Energy Management & Utilization

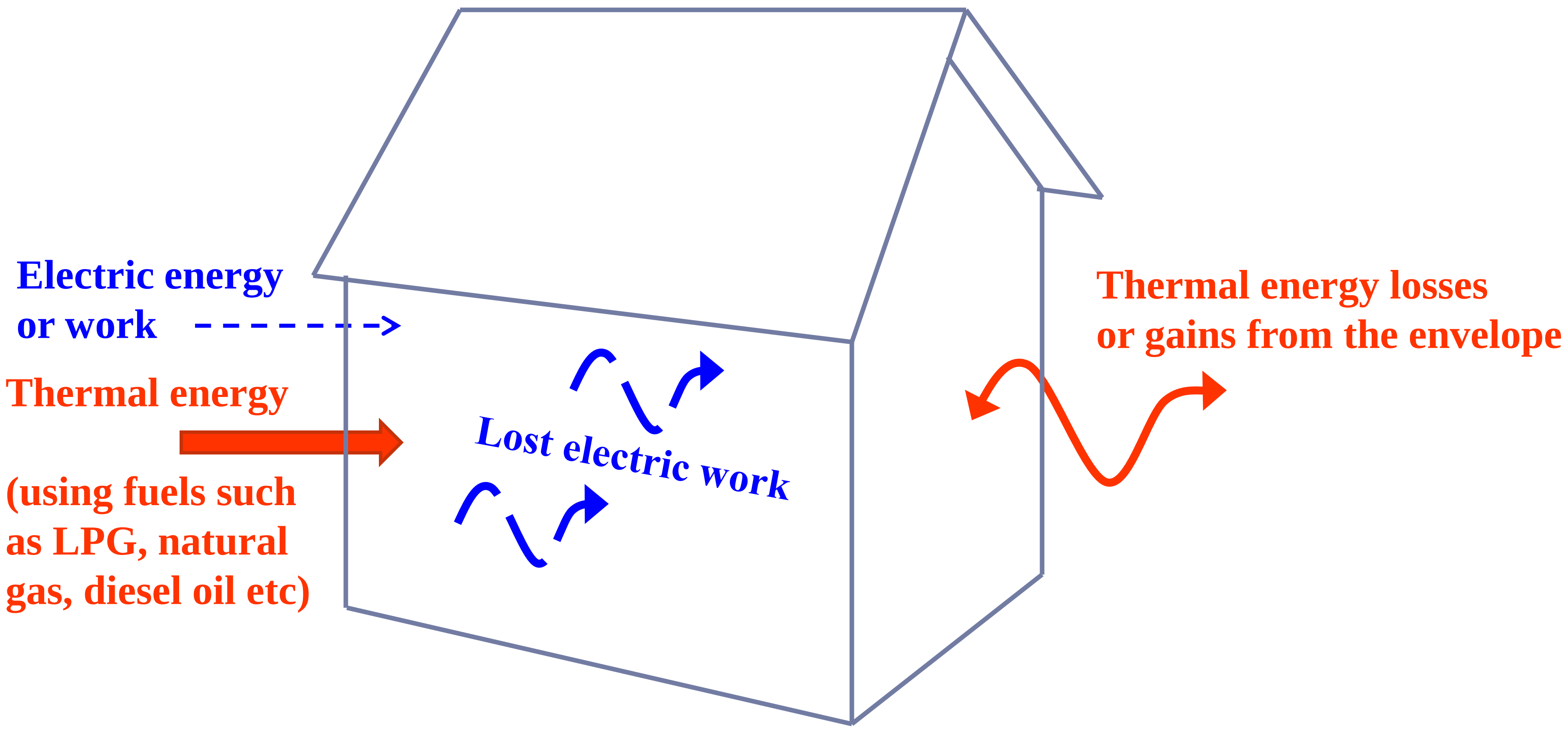
Chapter 5

Energy Management in Buildings

Prof. Dr. Ugur Atikol, cea

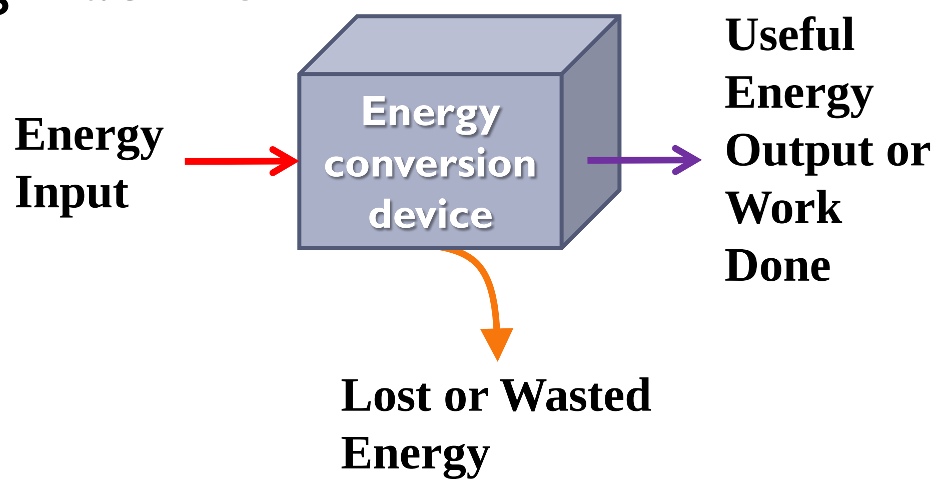
Director of EMU Energy Research Centre

Energy Utilization in Buildings



Energy Efficiency in Buildings

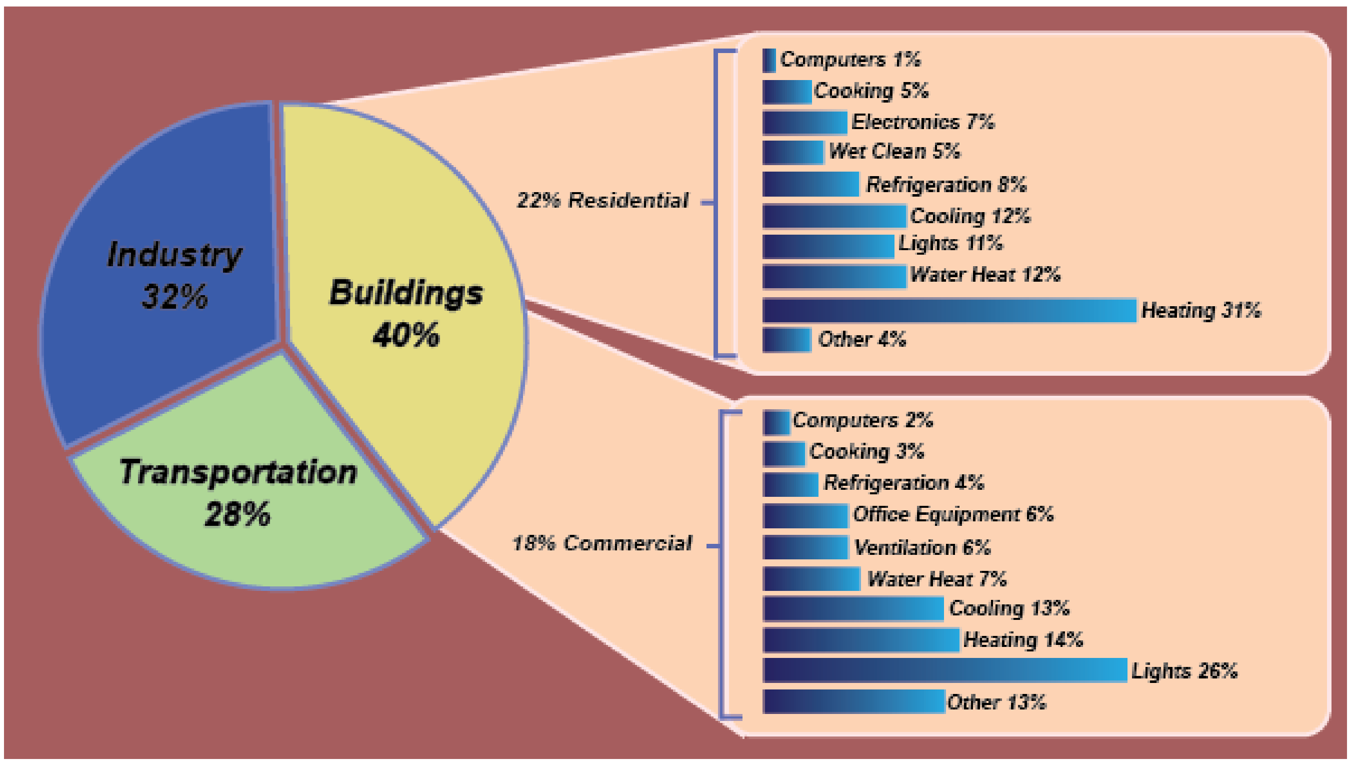
- Making more use of the available energy or doing the same amount of work with less energy
- Example: Washing the same laundry with less electricity in a washing machine



$$Efficiency = \frac{Useful\ Energy\ Output}{Energy\ Input}$$

Why buildings are important?

- Buildings consume large amounts of eneregy everywhere in the world.
- Buildings account for roughly **40%** of all U.S. energy use

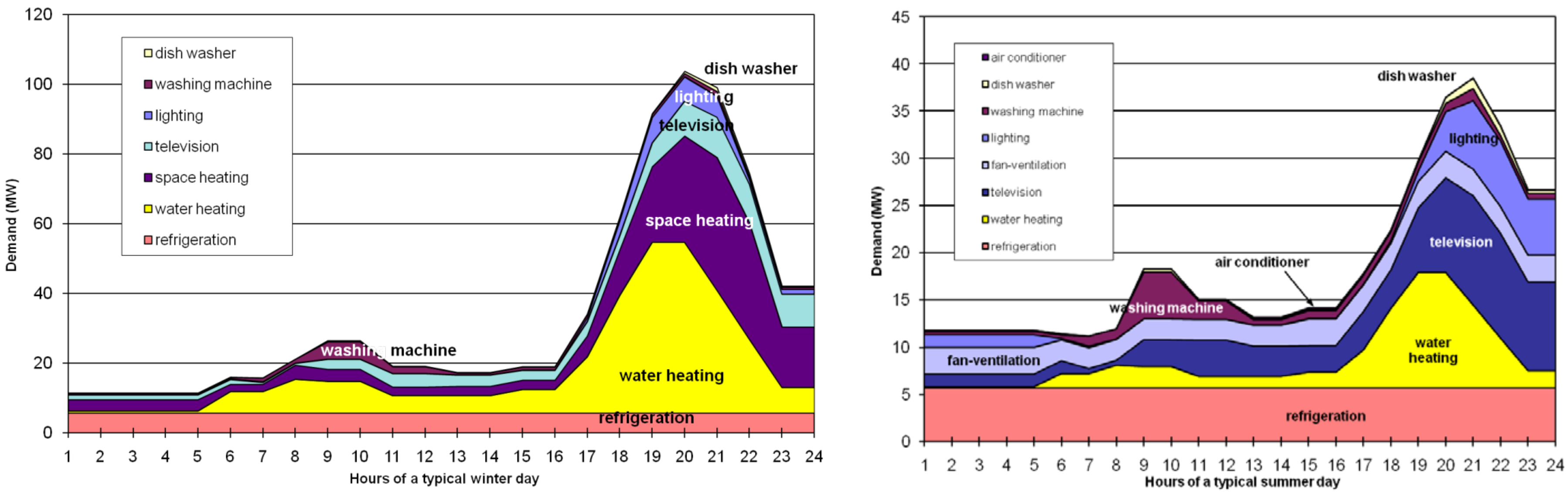


- Source: http://howcanihelpsandiego.com/lighter-side-of-green/

Energy Use in Buildings

- Residences:

Depending on seasons heaters, air conditioners, lighting, washing machines, television sets etc are used

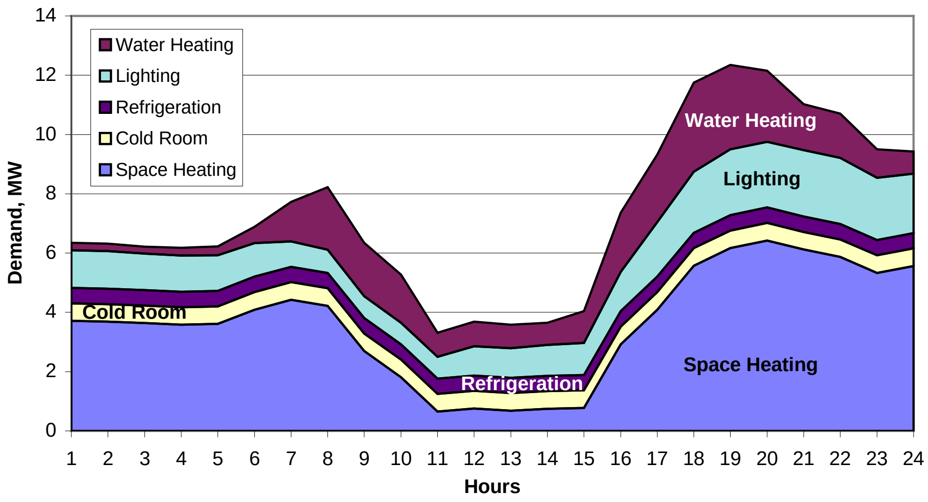


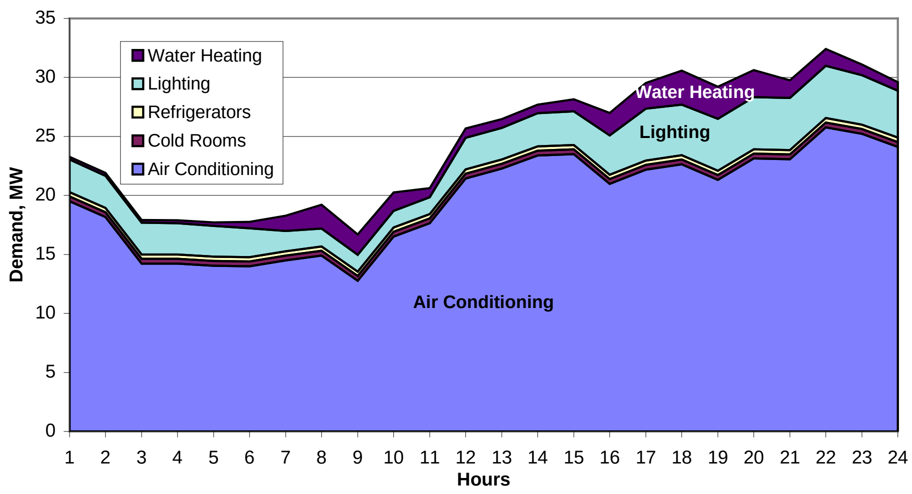
- Figures show the end-uses of residences in 1996 for N. Cyprus (*Source: Atikol et al., 1999*)

Energy Use in Buildings

- Hotels:

Depending on seasons heaters, air conditioners, lighting, refrigeration, television sets etc are used



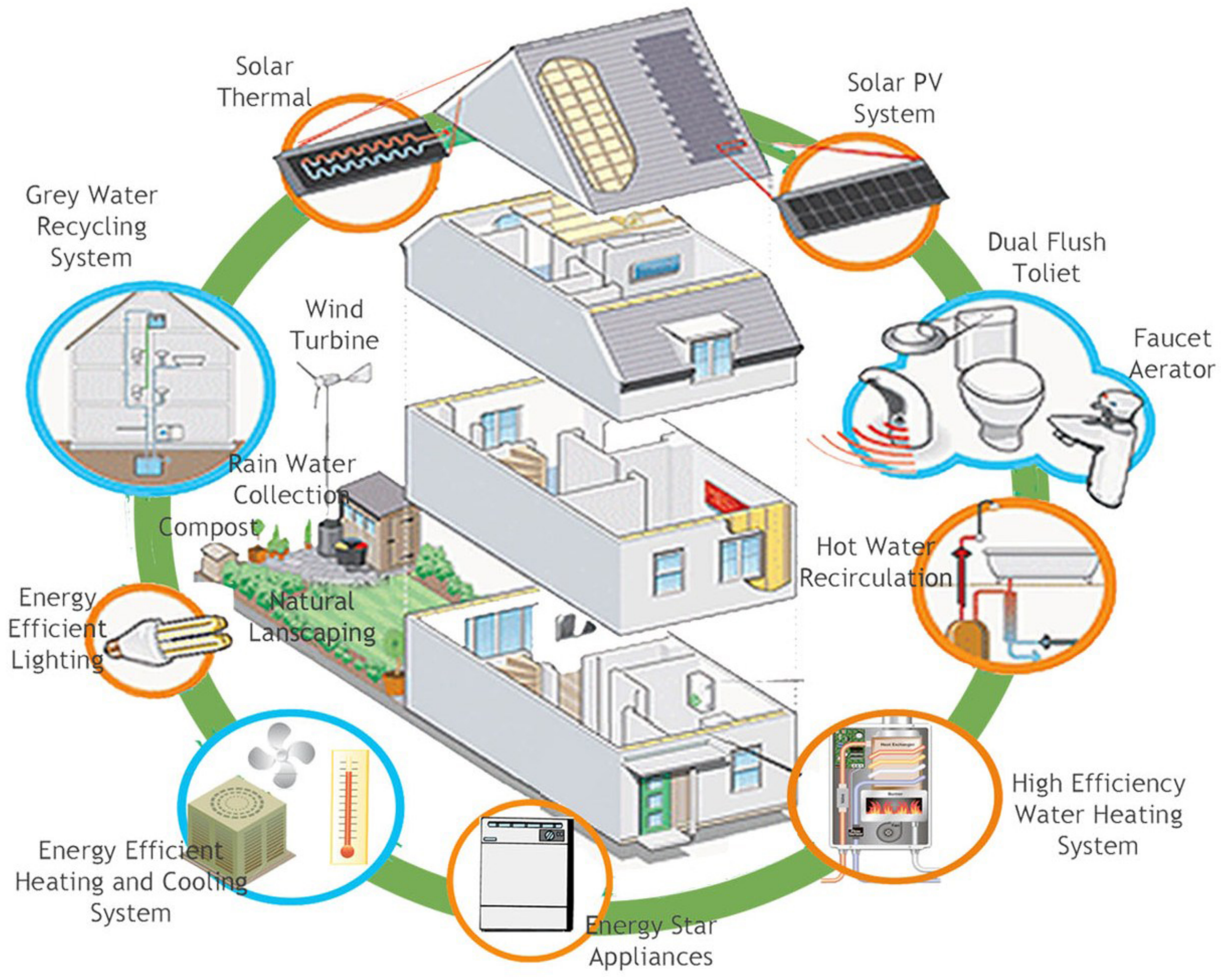


- Figures show the end-uses of hotels in 1997 for N. Cyprus (*Source: Atikol, 2004*)

Energy Efficiency Opportunities in Buildings

- Building Operation
- Building Envelope
- HVAC Systems
- HVAC Distribution Systems
- Water Heating Systems
- Lighting Systems
- Power Systems
- Energy Management Control Systems
- Heat Recovery Systems

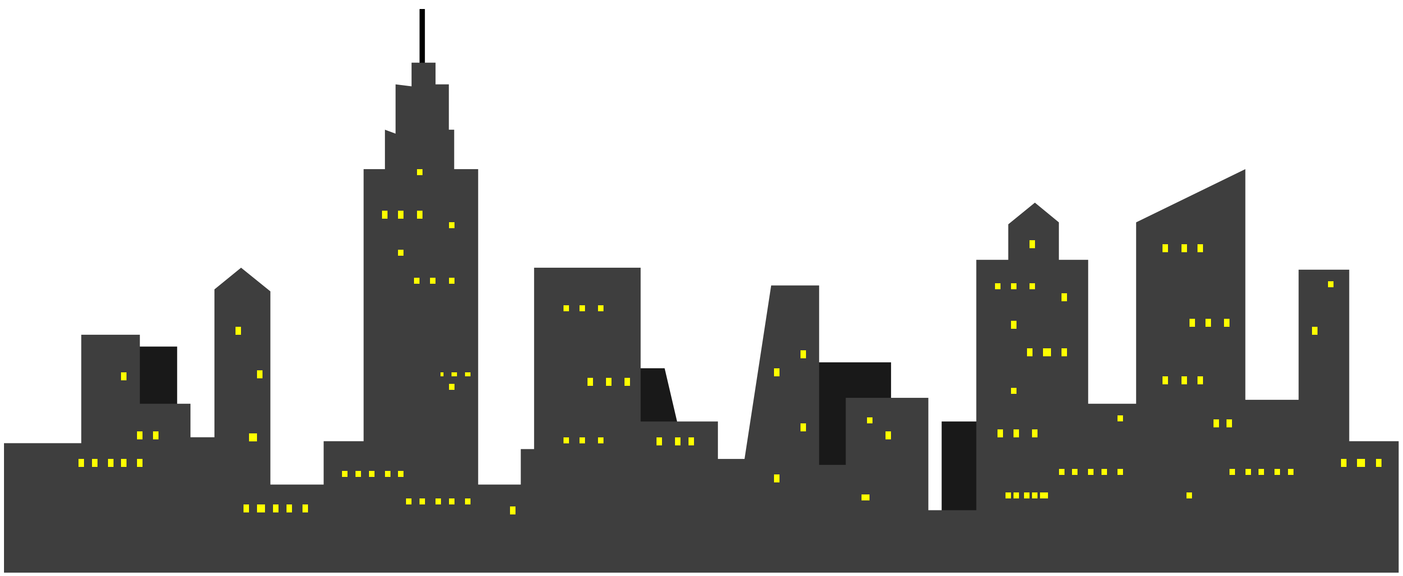
Renewable Energy and Energy Efficiency



- Source: http://lunar.thegamez.net/greentechnology/energy-efficient-house-plans/specialise-in-and-only-allow-house-designs-that-are-energy-efficient-1263x1040.jpg

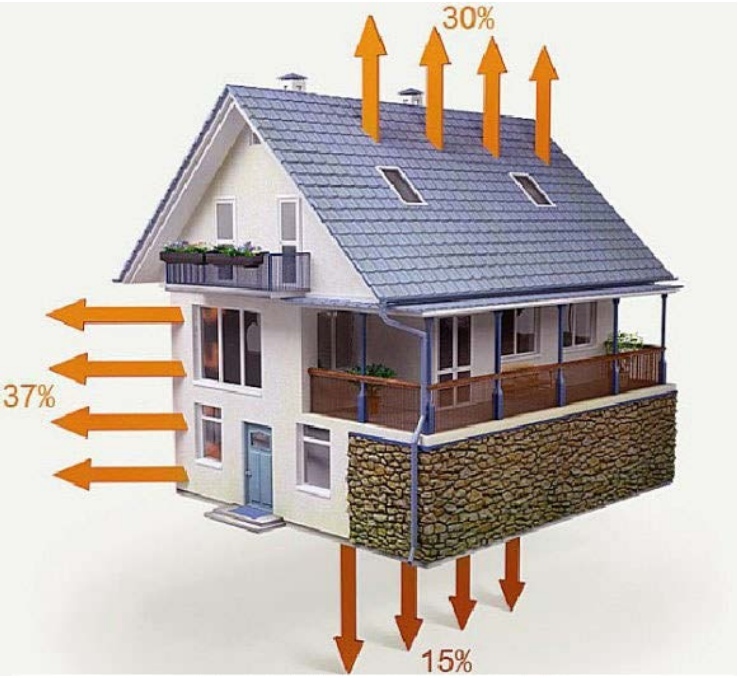
Building Opperation

When the building is not occupied, the building systems should be turned off or their operation reduced to a minimum.

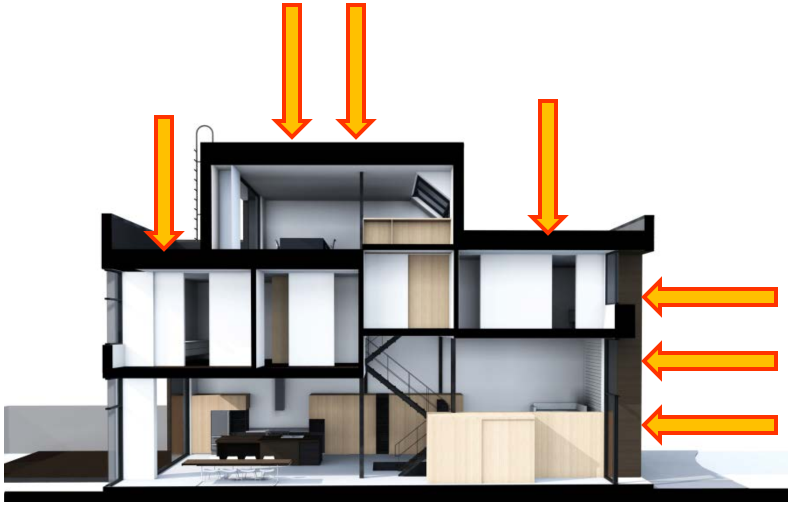


Building Envelope

Energy is saved when the heat exchange between the building and the outside environment is reduced and/or solar and internal heat gains are controlled.



Winter heat losses



Summer heat gains

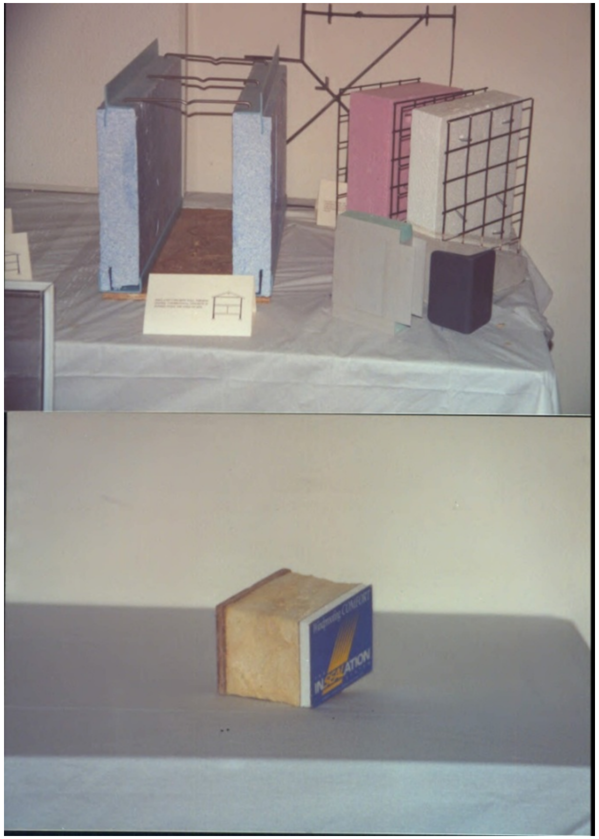
Building Envelope

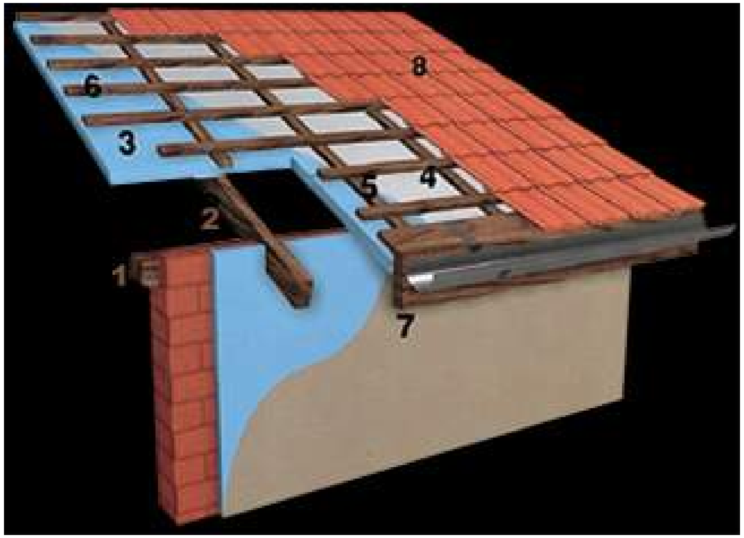
Energy is saved when the heat exchange between the building and the outside environment is reduced and/or solar and internal heat gains are controlled.

- **Thermal insulation**
- **Infiltration control**
- **Roof color**
- **Solar gains**
- **Window shading**
- **Landscaping**
- **Window quality**
- **Heat bridge**

Building Envelope

- Thermal Insulation





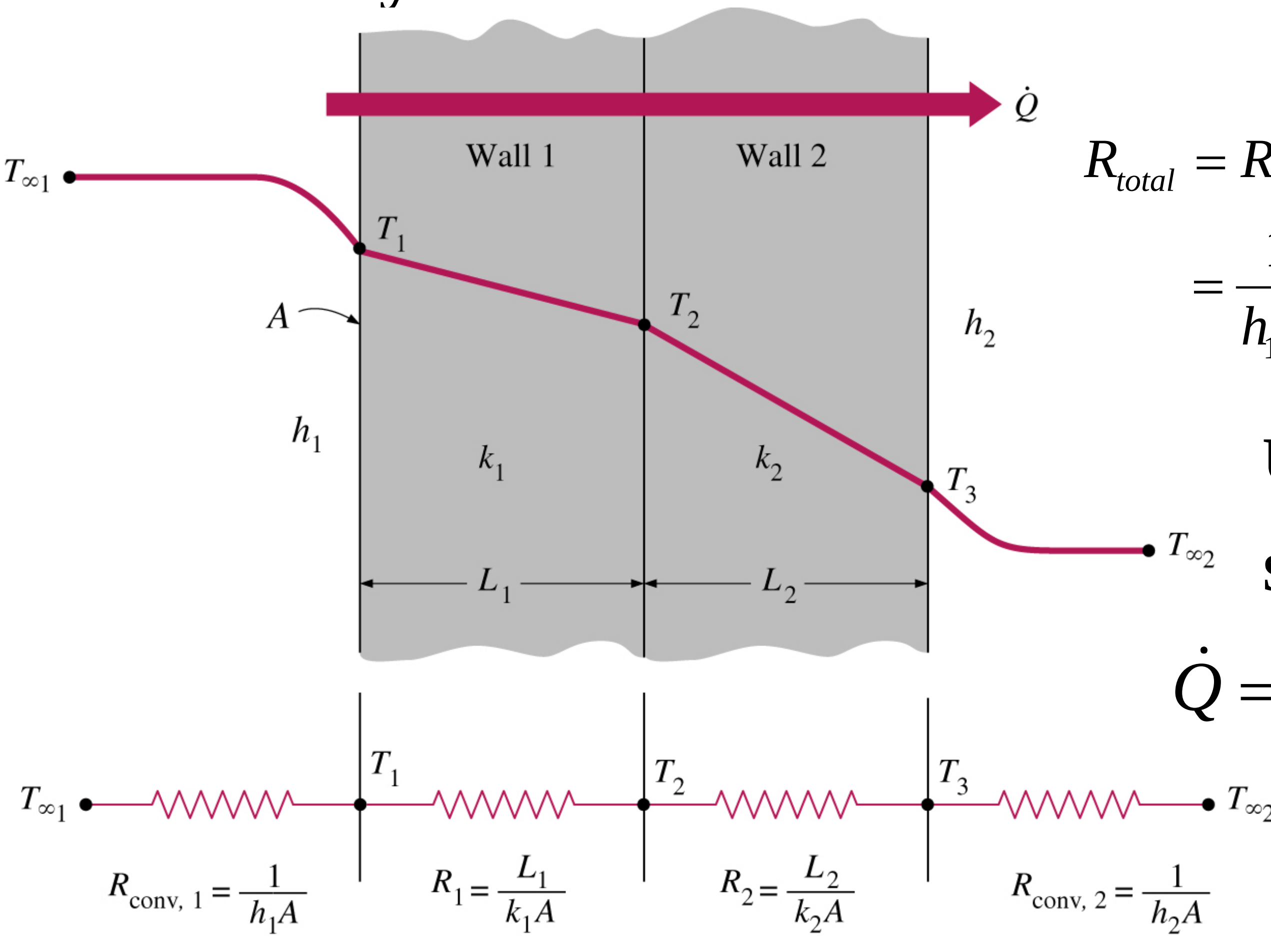
1) Cushion,
2) Beam rafter,
3) Roofmate* PS thermal resistance board
4) Water proofing membrane
5) Tilling battens
6) Counter battens
7) Face wood
8) Roof cover (roof tiles, schingle)

Source:http://www.bulak.net/dow_roofmate_ps_Eng.asp

Building Envelope

<u>Insulation:</u>

Multilayer Plane Walls



$$\dot{Q} = \frac{T_{\infty,1} - T_{\infty,2}}{R_{total}}$$

$$R_{total} = R_{conv,1} + R_{wall,1} + R_{wall,2} + R_{conv,2}$$

$$= \frac{1}{h_1 A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{1}{h_2 A}$$

U-value = 1/R_{total}

Such that:

$$\dot{Q} = U \times A \times (T_{\infty,1} - T_{\infty,2})$$

Building Envelope

<u>Windows:</u>

Multi-glazing Windows

Radiation heat transfer:

$$\dot{Q}_{rad} = \varepsilon\sigma A\left(T_s^4 - T_{surr}^4\right)$$

Heat losses through windows:

$$\dot{Q} = U \times A \times (T_{\infty,1} - T_{\infty,2})$$

Building Envelope: *Example*

Heat loss through a single pane window

Glass area: A = 0.8m × 1.5m = 1.2 m²

k = 0.78 W/m-°C.

$$R_i = R_{conv,1} = \frac{1}{h_1 A} = \frac{1}{(10\text{W/m}^2.^\circ\text{C})(1.2\text{m}^2)} = 0.08333^\circ\text{C/W}$$

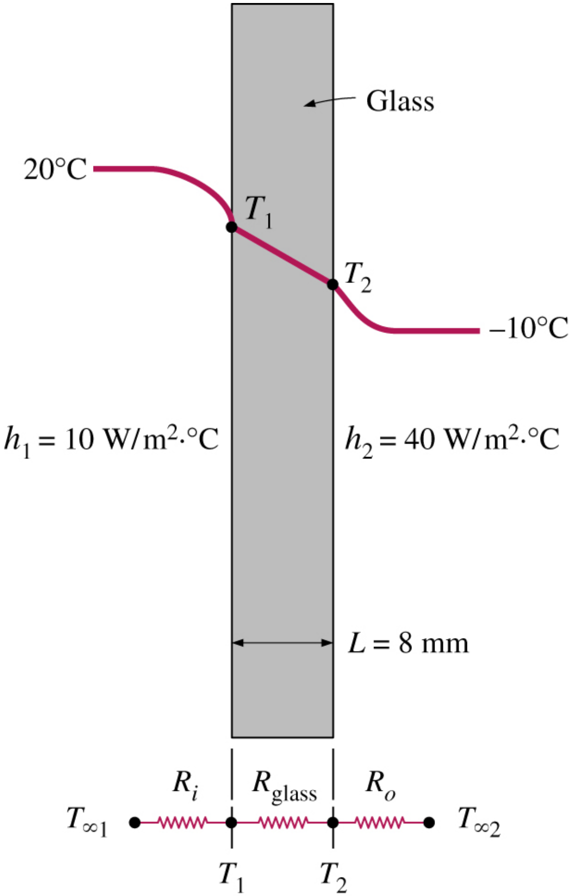
$$R_{glass} = \frac{L}{k} = \frac{0.008\text{m}}{(0.78\text{W/m}.^\circ\text{C})(1.2\text{m}^2)} = 0.00855^\circ\text{C/W}$$

$$R_o = R_{conv,2} = \frac{1}{h_2 A} = \frac{1}{(40\text{W/m}^2.^\circ\text{C})(1.2\text{m}^2)} = 0.02083^\circ\text{C/W}$$

$$R_{total} = R_{conv,1} + R_{glass} + R_{conv,2} = 0.08333 + 0.00855 + 0.02083 = 0.1127^\circ\text{C/W}$$

$$\dot{Q} = \frac{T_{\infty,1} - T_{\infty,2}}{R_{total}} = \frac{[20-(-10)]^\circ\text{C}}{0.1127^\circ\text{C/W}} = 266\text{W}$$

$$\dot{Q} = \frac{T_{\infty,1} - T_1}{R_{conv,1}} \rightarrow T_1 = T_{\infty 1} - \dot{Q}R_{conv,1} = -2.2^\circ\text{C}$$



→Formation of fog or frost on the surface

Building Envelope: *Example*

Heat loss through a double pane window

$$R_i = R_{conv,1} = \frac{1}{h_1 A} = 0.08333^{o}\,\mathrm{C/W}$$

$$R_1 = R_3 = R_{glass} = \frac{L_1}{k_1 A} = 0.00427^{o}\,\mathrm{C/W}$$

$$R_2 = R_{air} = \frac{L_2}{k_2 A} = 0.3205^{o}\,\mathrm{C/W}$$

$$R_o = R_{conv,2} = \frac{1}{h_2 A} = 0.02083^{o}\,\mathrm{C/W}$$

$$R_{total} = R_{conv,1} + R_{glass,1} + R_{air} + R_{glass,2} + R_{conv,2} = 0.4332^{o}\,\mathrm{C/W}$$

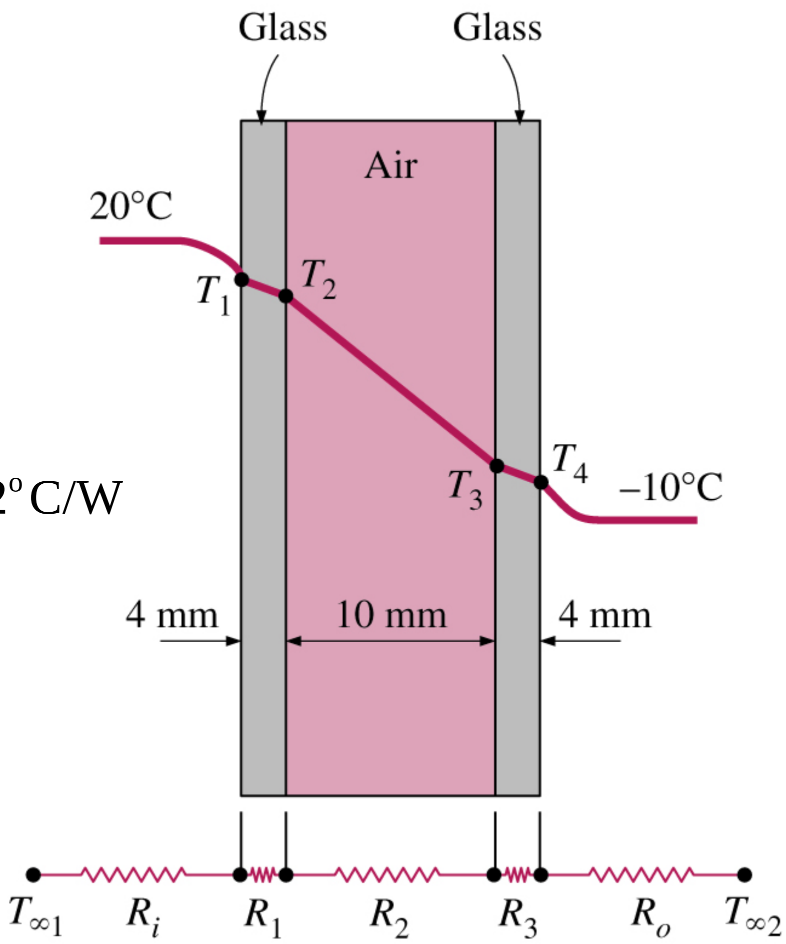
$$\dot{Q} = \frac{T_{\infty,1} - T_{\infty,2}}{R_{total}} = \frac{[20-(-10)]^{o}\,\mathrm{C}}{0.4332^{o}\mathrm{C/W}} = 69.2\mathrm{W}$$

which is 1/4th of the previous result.

Inner surface temperature of the window:

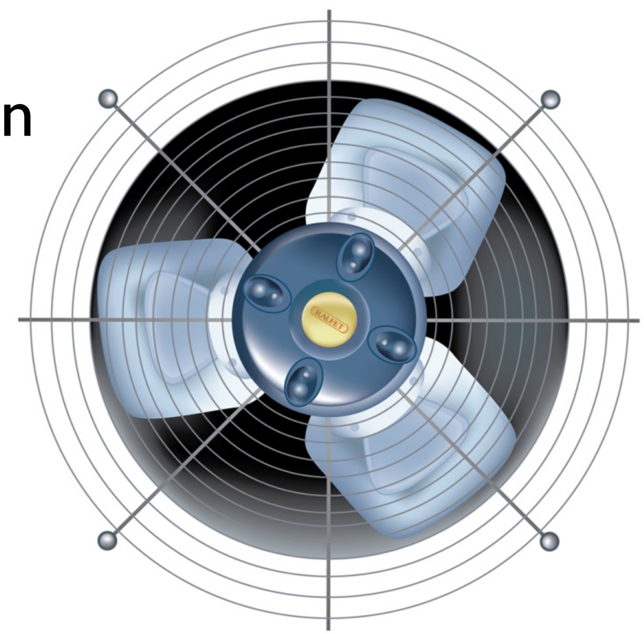
$$T_1 = T_{\infty 1} - \dot{Q}R_{conv,1} = 14.2^{o}\,\mathrm{C}$$

→ no fogging



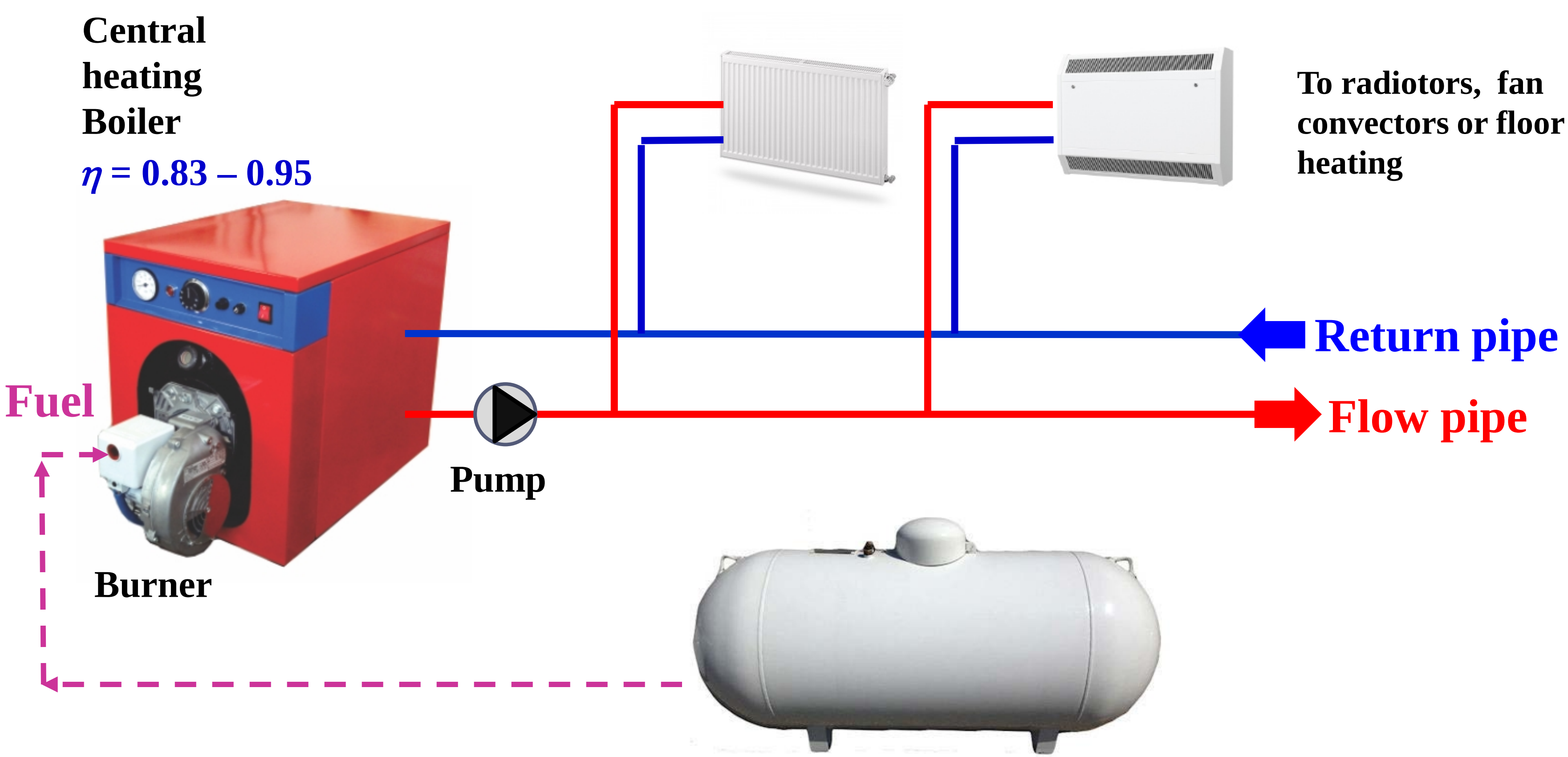
HVAC Systems

- Use efficient equipment
- Ventilation requirements must be correctly determined
- Efficiently designed distribution system
- Controls for efficiency
- Pay attention to hours of operation
- Building envelope



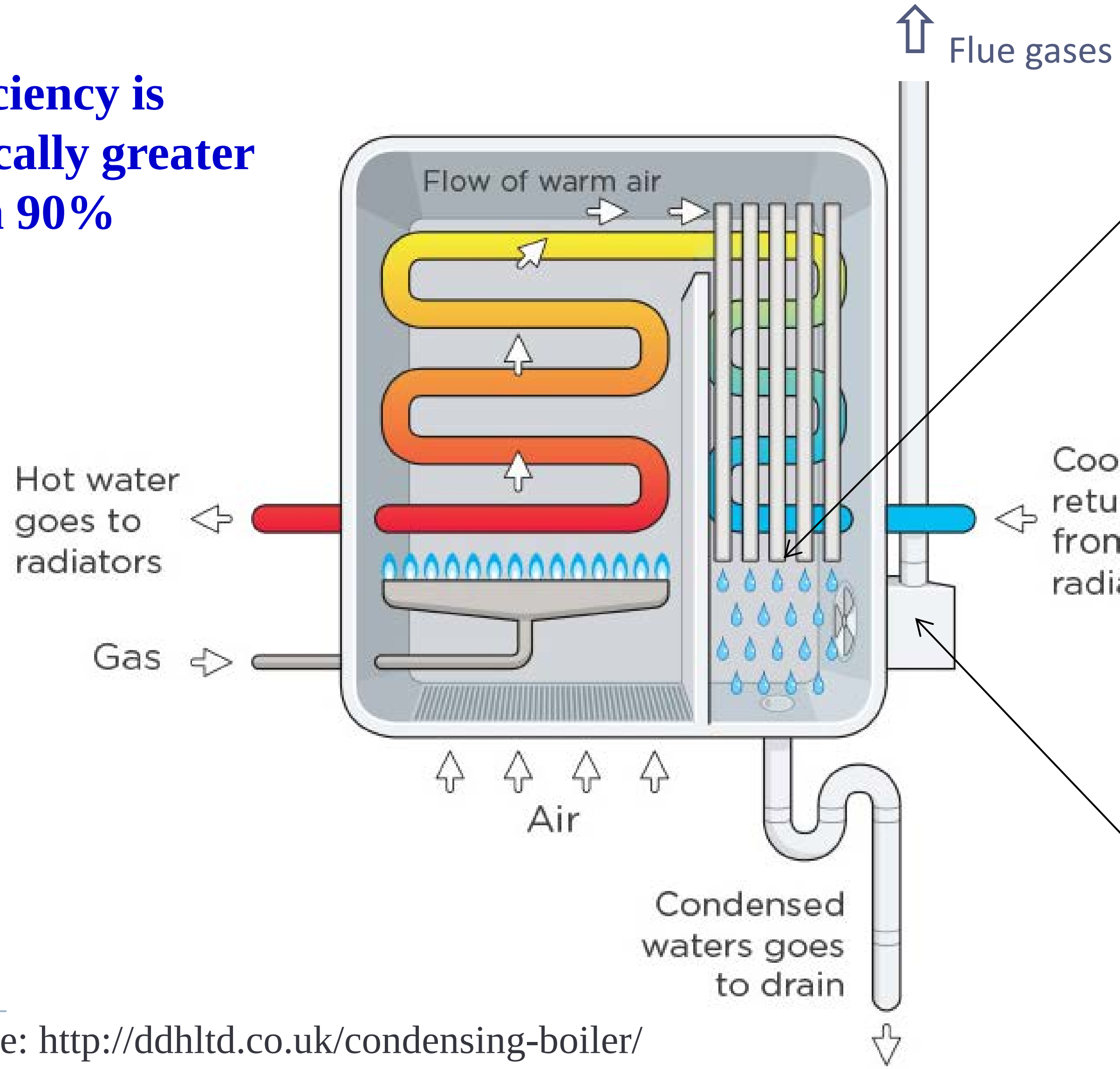
Central Heating with Boilers

Central Heating with Boilers



Condensing Boiler

Efficiency is typically greater than 90%



Water vapor from the exhaust gas is turned into liquid condensate

Fan

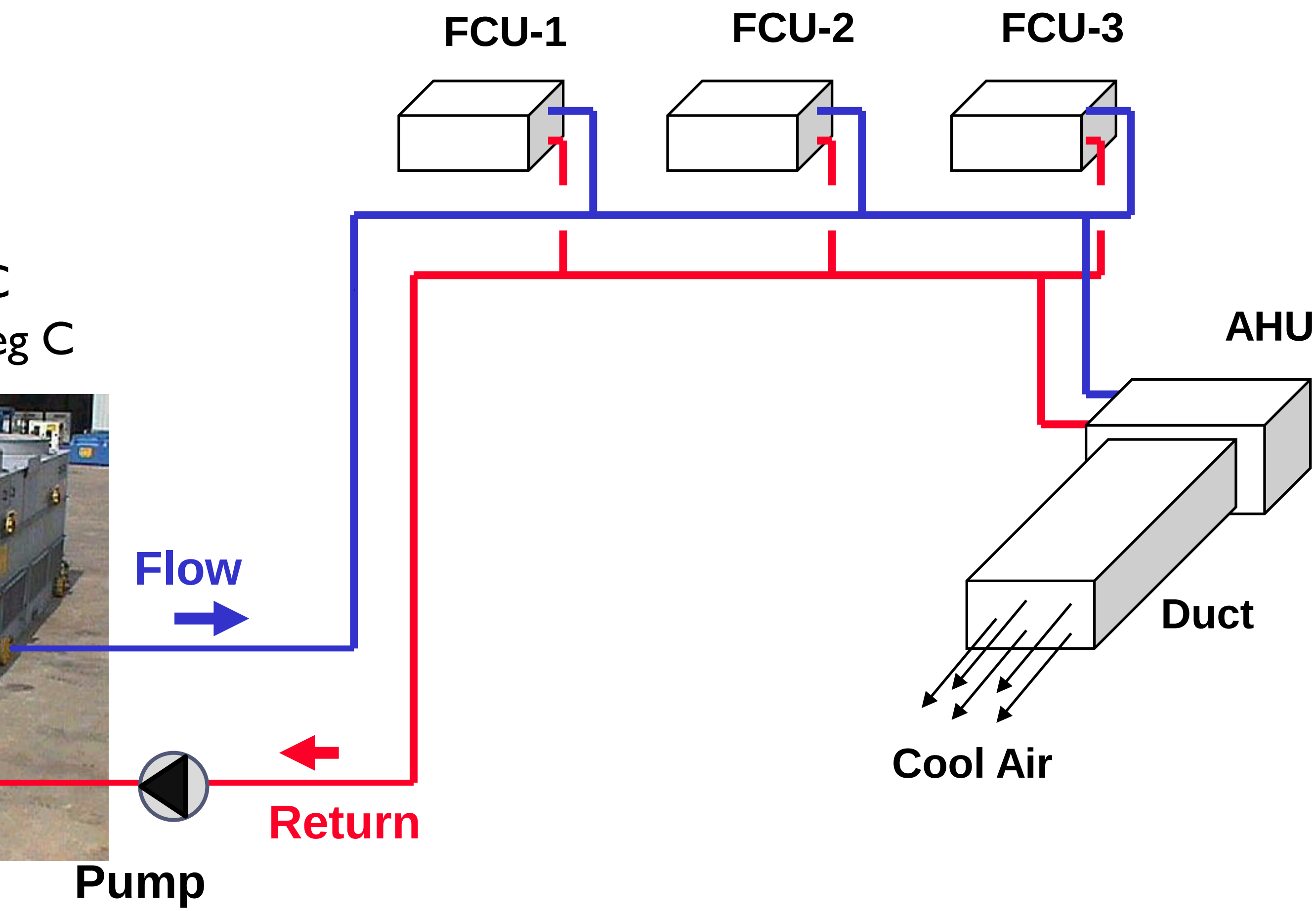
Source: http://ddhltd.co.uk/condensing-boiler/

HVAC Systems

Central Cooling with Chillers

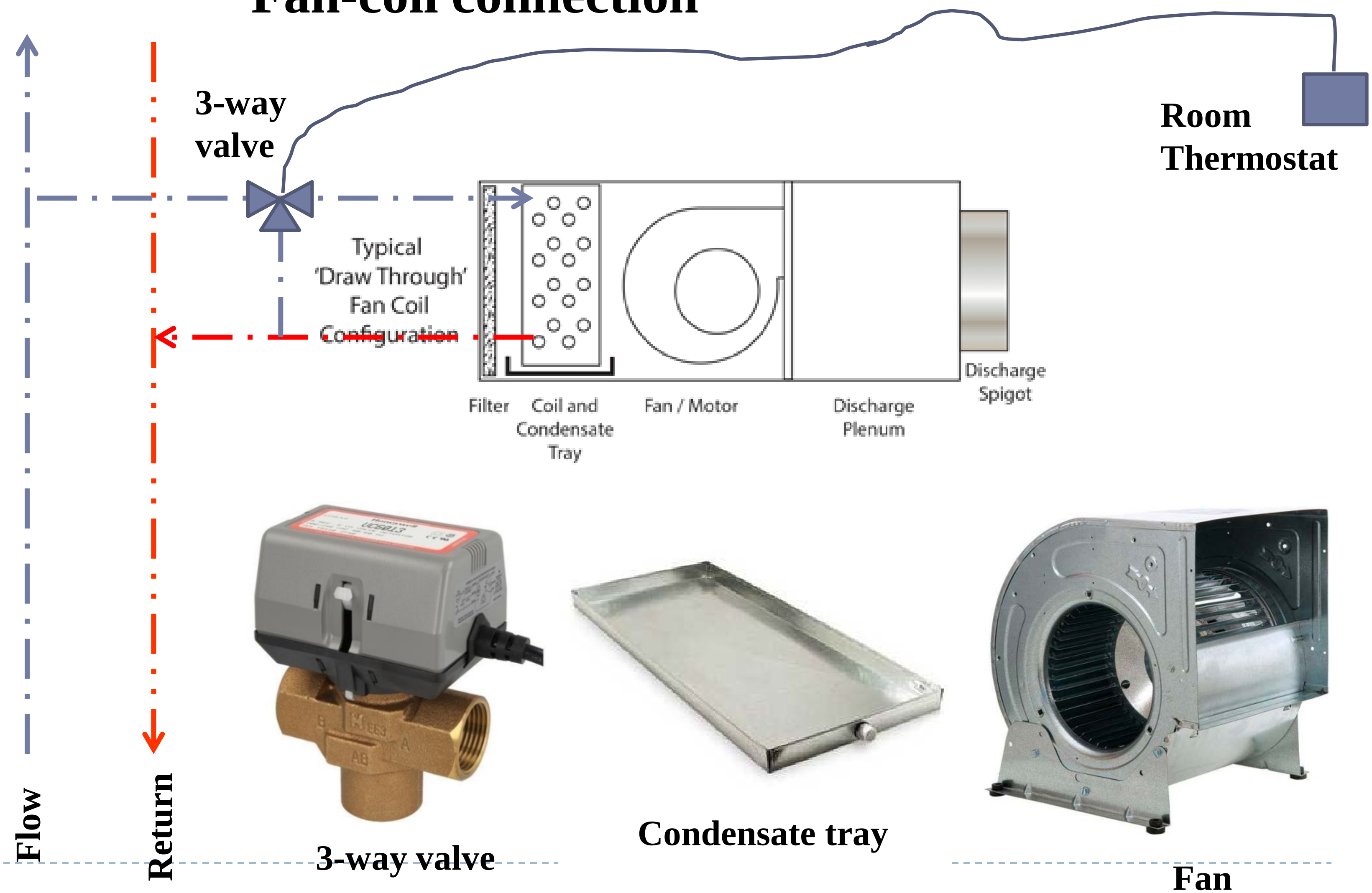
***COP* = 2.5 – 3.5**

Flow water ~ 7 deg C
Return water ~ 13 deg C

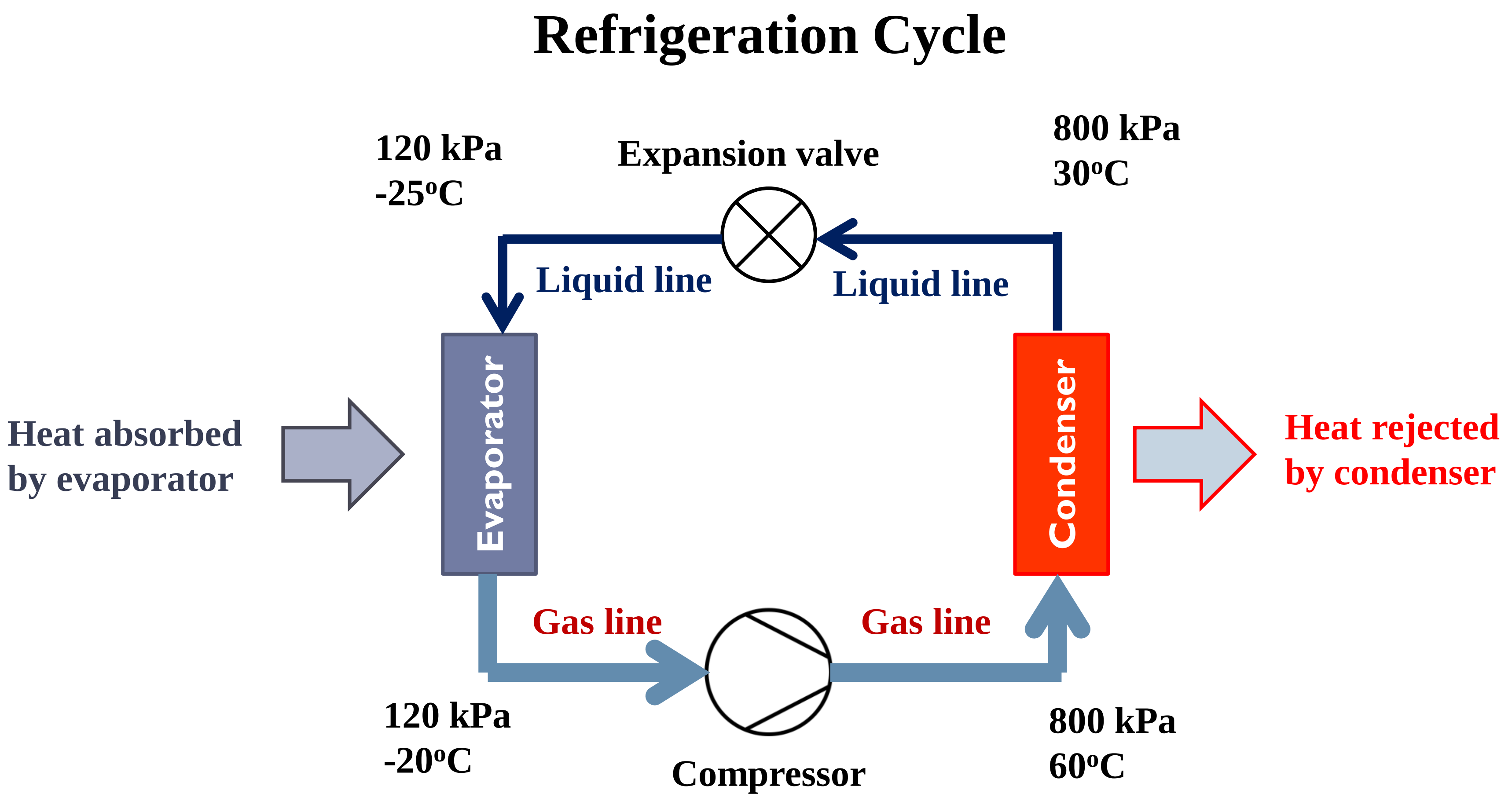


HVAC Systems

Fan-coil connection



HVAC Systems



HVAC Systems

Variable Speed Drives (VSDs) for Energy Efficiency in HVAC Systems

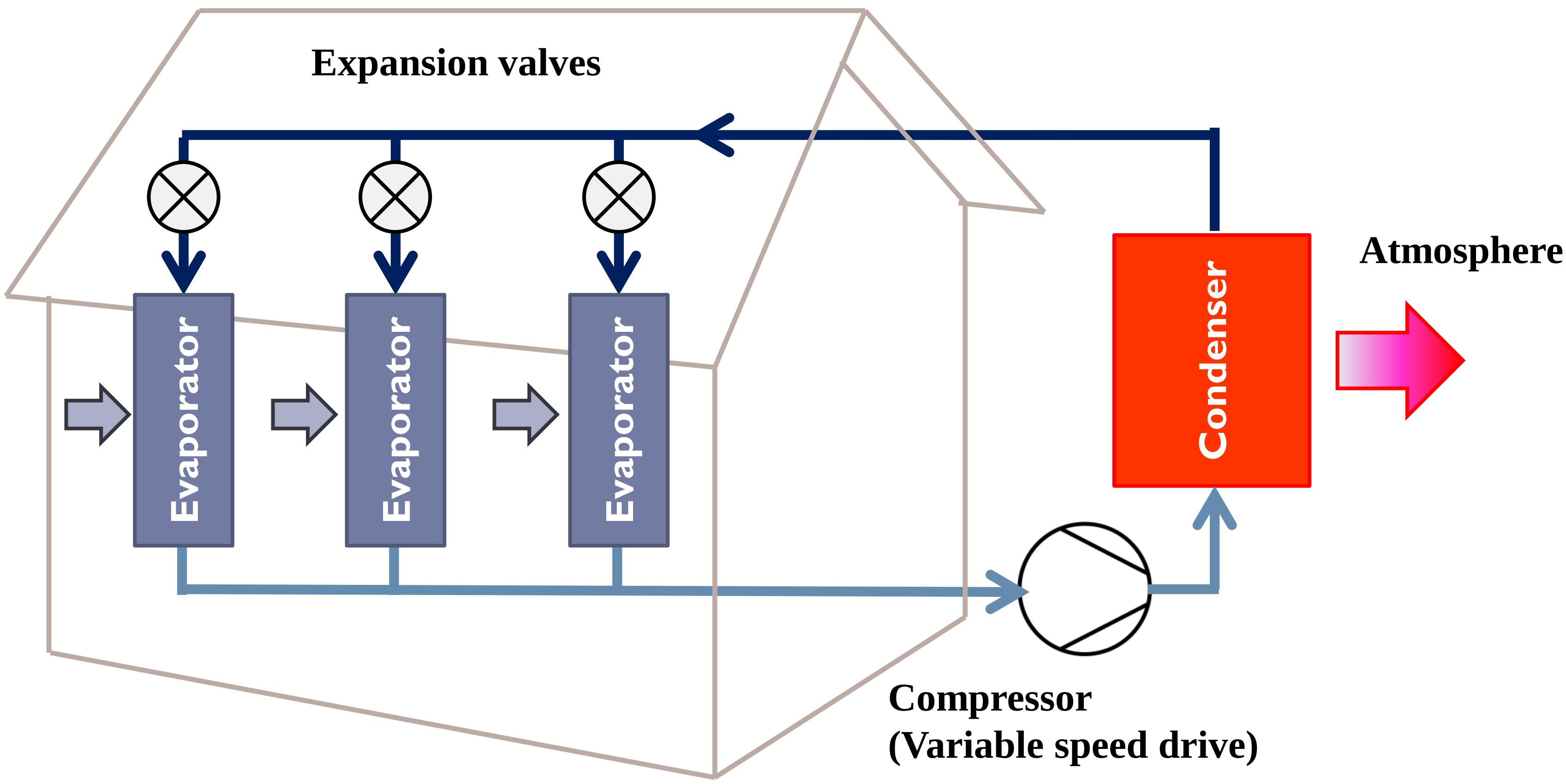
- Large savings can be achieved by using variable speed drives for fans, compressors and pumps. The cube law says:

$$\frac{kW_{new}}{kW_{old}} = \frac{[RPM_{new}]^3}{[RPM_{old}]^3}$$

- Example: If fan speed is reduced by a half, the power consumed is reduced by $\frac{1}{8}$.

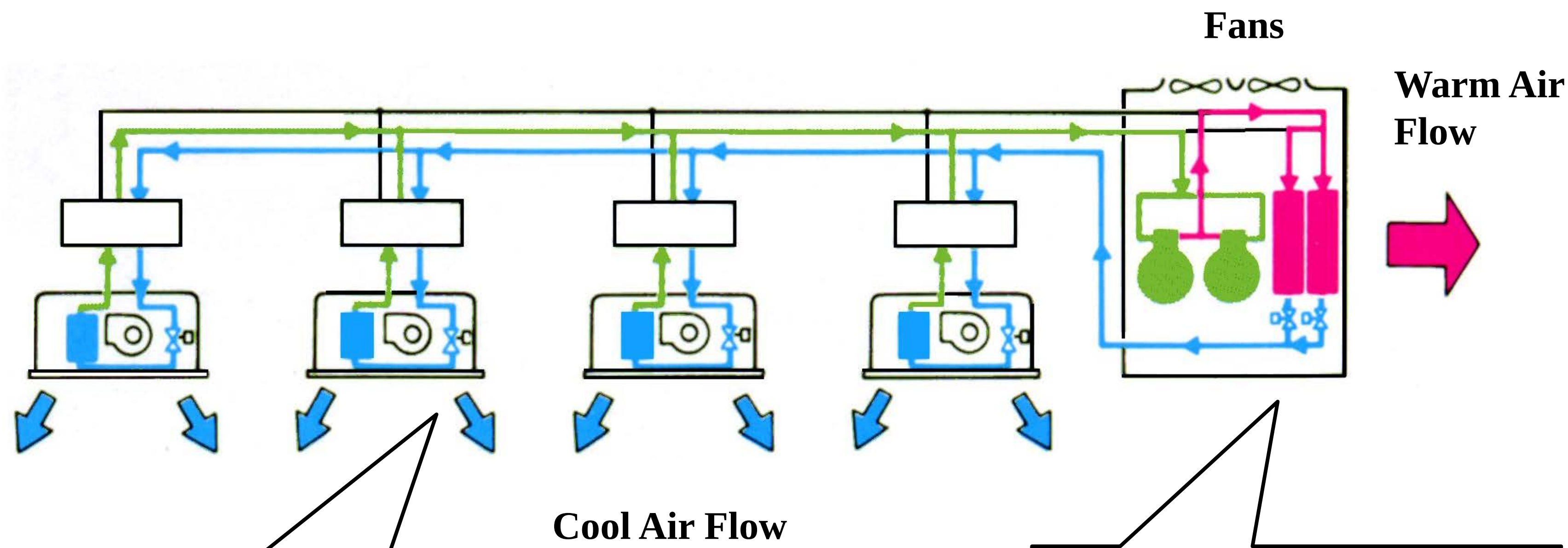
HVAC Systems

Variable Refrigerant Volume (VRV) System



HVAC Systems

VRV System in summer mode

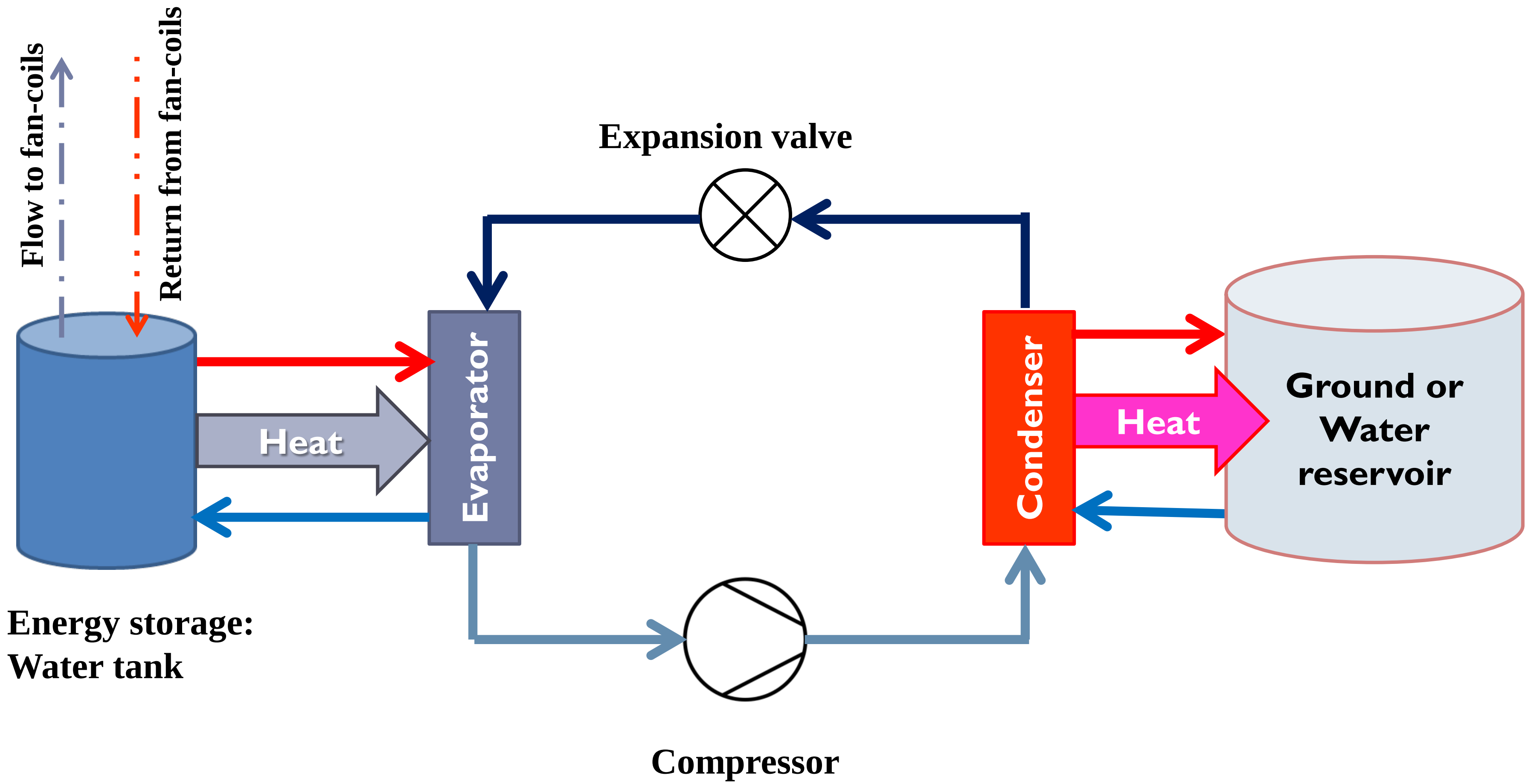


Indoor units comprise of:
- expansion valve
- evaporator (condenser)
- fan

Outdoor unit comprise of
- condenser (evaporator)
- compressor
- Fans

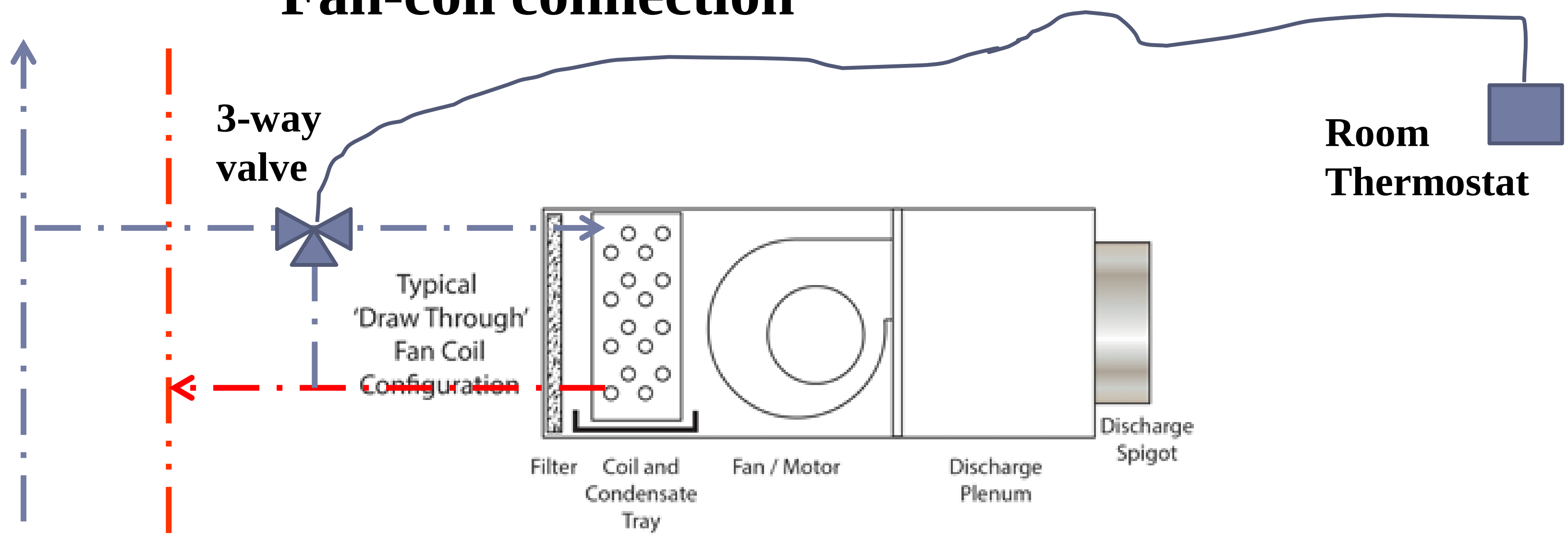
HVAC Systems

Water cooling/heating with chillers or heat pump systems



HVAC Systems

Fan-coil connection



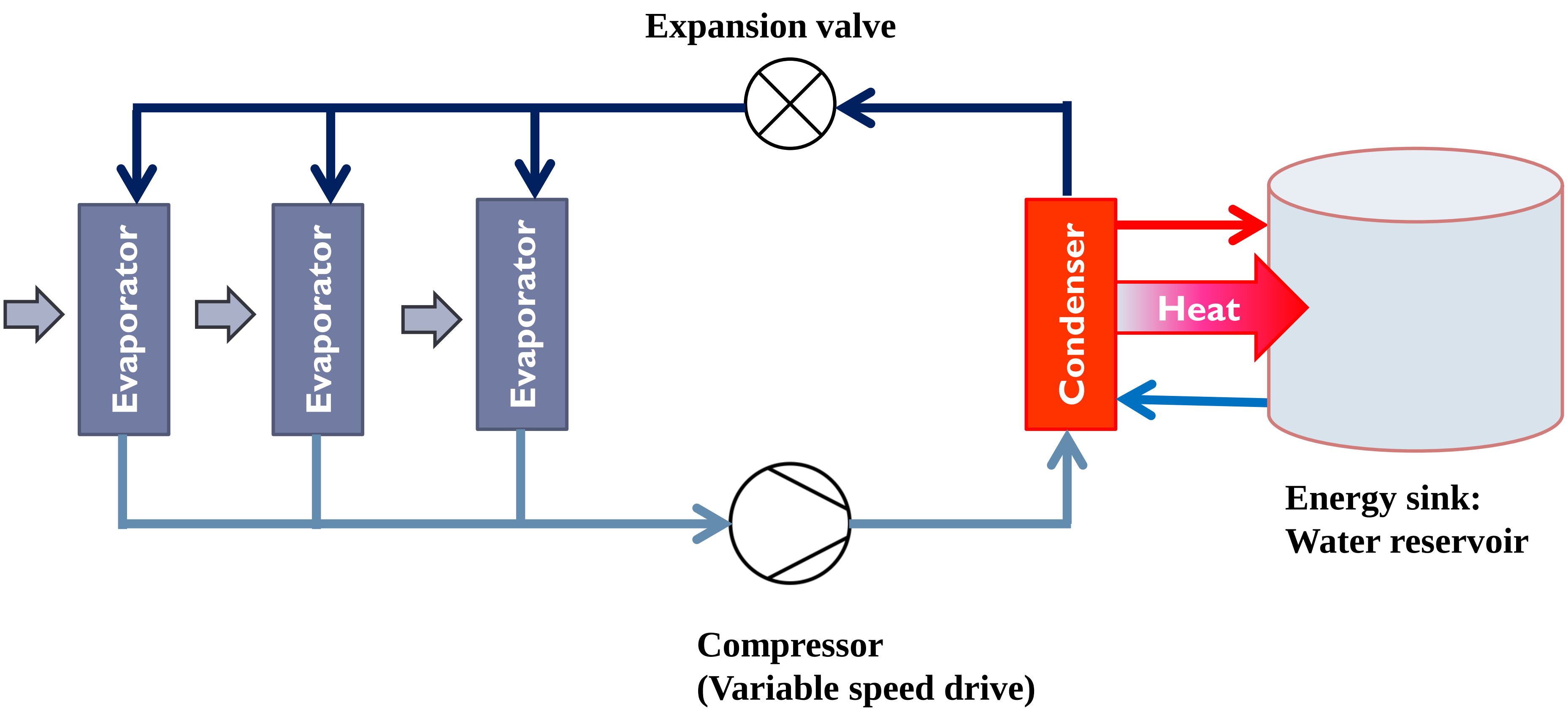
3-way valve

Condensate tray

Fan

HVAC Systems

Ground or Water Source VRV System



Heating and Cooling Degree Days

- Used to evaluate effects of weather
- Heating and cooling degree days (*HDD*, *CDD*)
- Balance point temperature, T_{bal} is defined as that value of the outdoor temperature, where (for a specified value of indoor temperature, T_i) the total heat loss is equal to the free heat gain (from the sun, occupants etc.)
- The standard value of the balance point temperature is 18,3 °C
- If K_{tot} is the total heat loss of the building:

$$K_{tot}(T_i - T_{bal}) = \dot{Q}_{gain}$$

Heating and Cooling Degree Days

- T_o = Average daily temperature
- *HDD* = balance point temp – average daily temperature
  - Daily high temperature: 6,7 °C
  - Daily low temperature: -2,2 °C
  - Daily average temperature = (6,7 – 2,2) / 2 = 2,2
  - *HDD* = 18,3 – 2,2 = 16,1 HDD for the day
- For 365 days:

$$HDD = \sum_{j=1}^{365} (T_{bal} - T_{o,j})$$

- Heating is only needed when T_o drops below T_{bal}

Heating and Cooling Degree Days

- *For estimating annual heating that uses a heating system with efficiency* η *:*

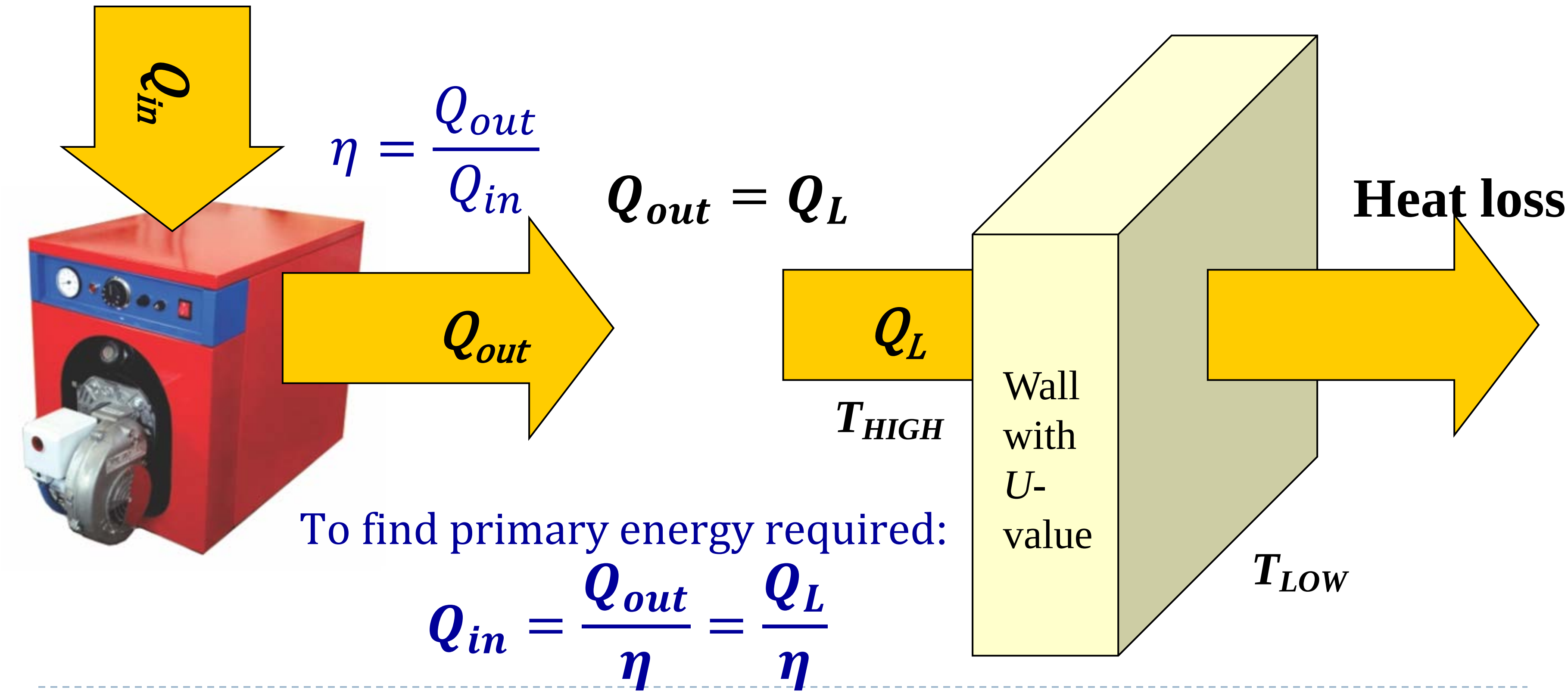
$$Q_{h,yr} = \frac{K_{tot}}{\eta} \times HDD$$

- Degree-days for a balance temperature of 18°C in Europe or 65°F (18.3°C) in the United States have been widely tabulated.

Estimating Annual Boiler Energy with HDD method

Annual heat loss through a building component:

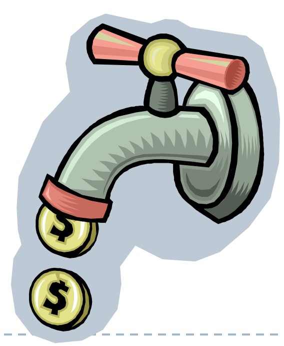
$$\boldsymbol{Q_L}\left(\frac{\text{Wh}}{\text{year}}\right) = \boldsymbol{U}\left(\frac{\text{W}}{\text{m}^2\text{°C}}\right) \times \boldsymbol{A}(\text{m}^2) \times \boldsymbol{HDD}\left(\frac{\text{°C days}}{\text{year}}\right) \times 24\,\frac{\text{h}}{\text{day}}$$



Water Heating Systems

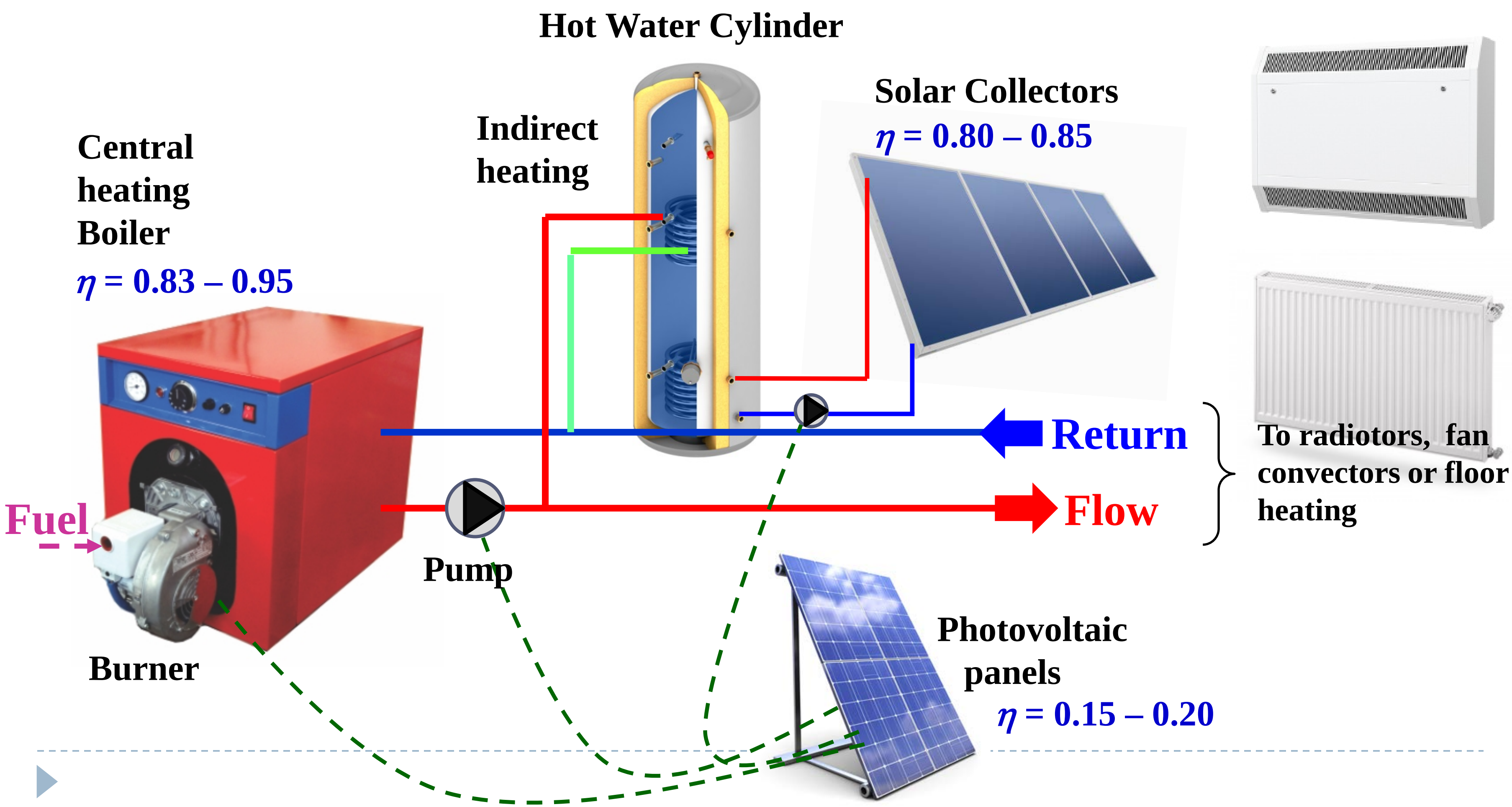
Water heating energy is conserved by reducing load requirements, reducing distribution losses, and improving the efficiency of the water heating systems.

- **Flow Restrictors**
- **Tank and Pipe Insulation**
- **Supply Temperatures**
- **Leaks and Drips**
- **Seasonal Operation**
- **Equipment Efficiency**



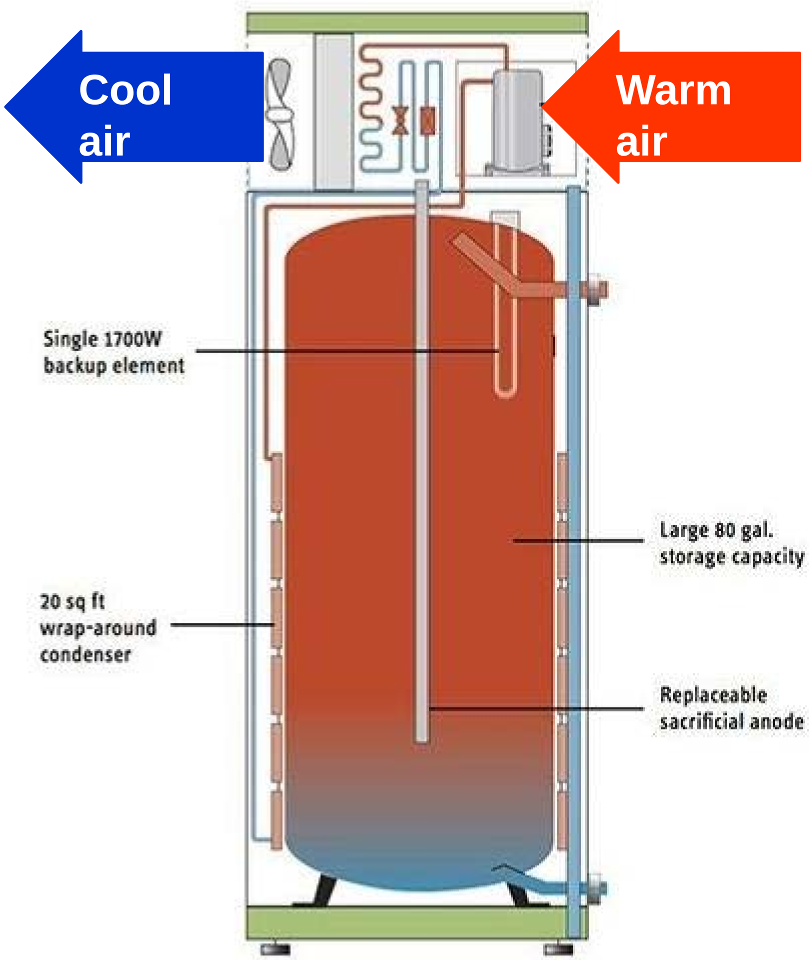
Water Heating Systems

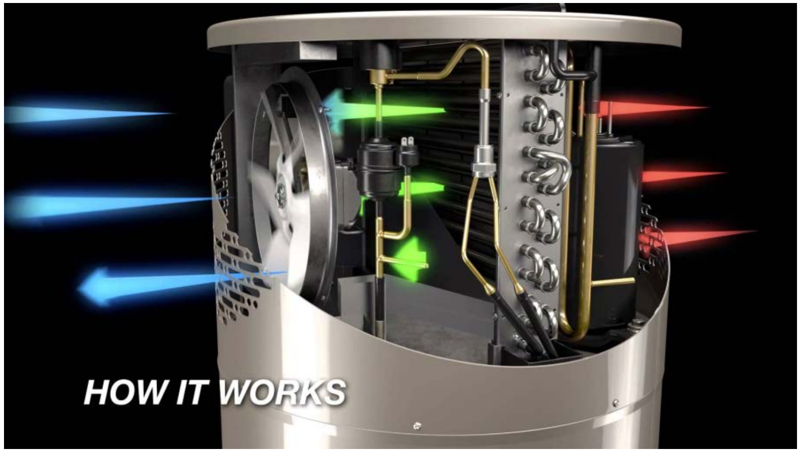
- Hot water generation with central boiler

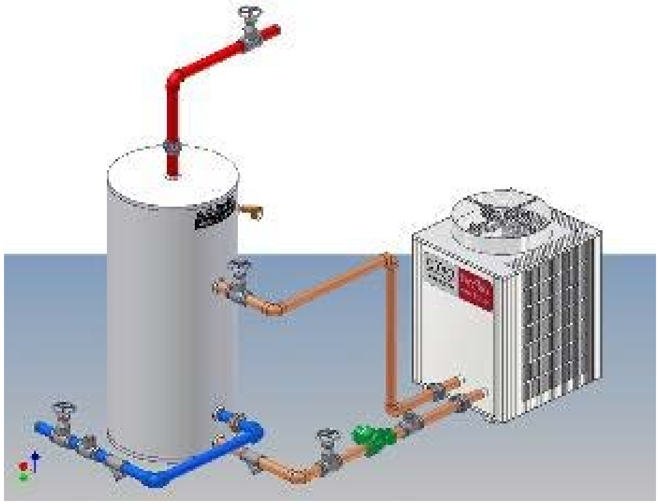


Water Heating Systems

- Hot water generation with heat pump (*COP* = 3.0 – 5.0)

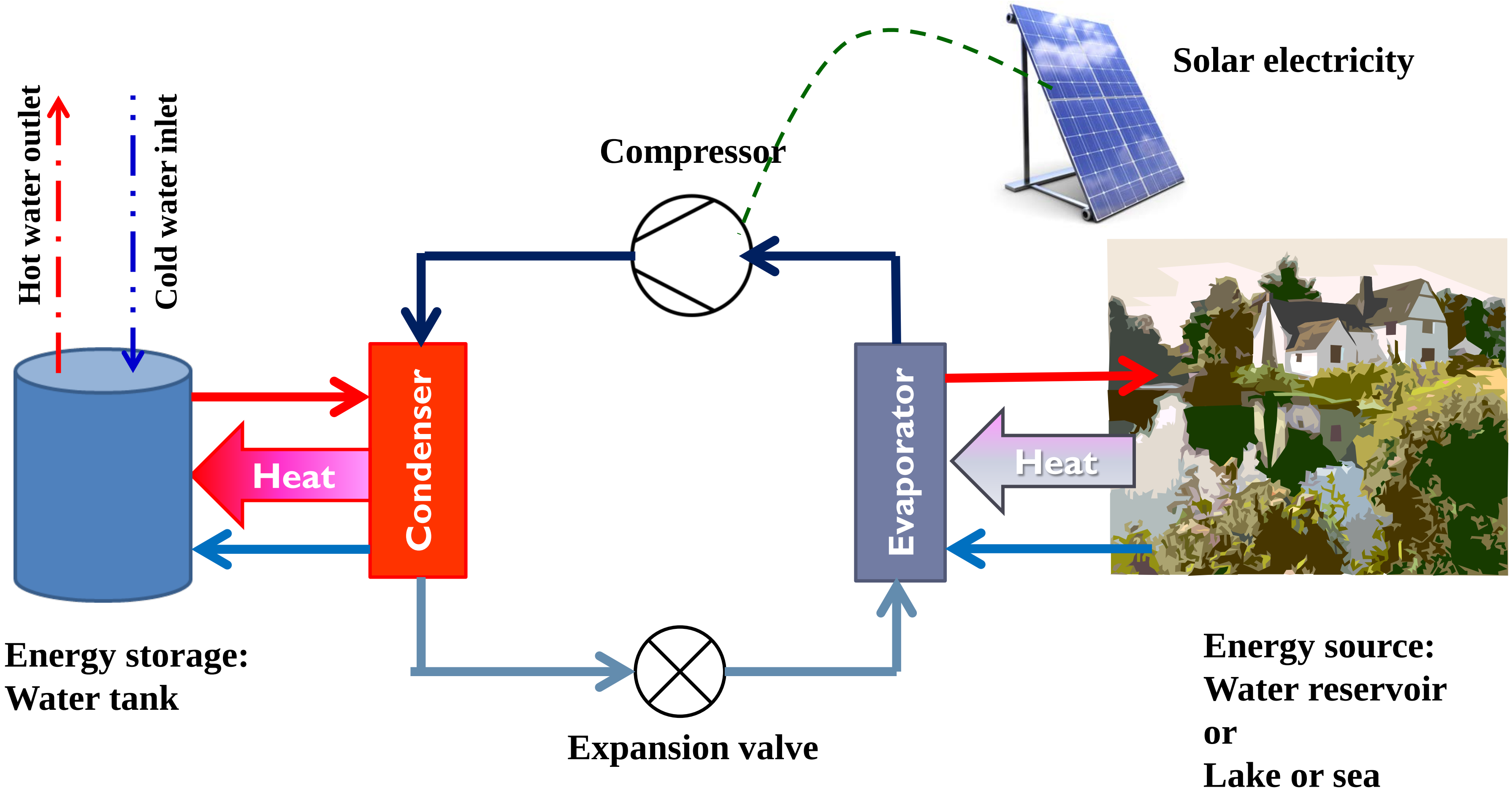




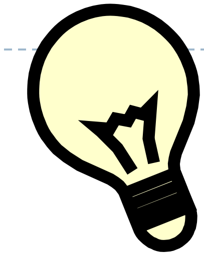


Water Heating Systems

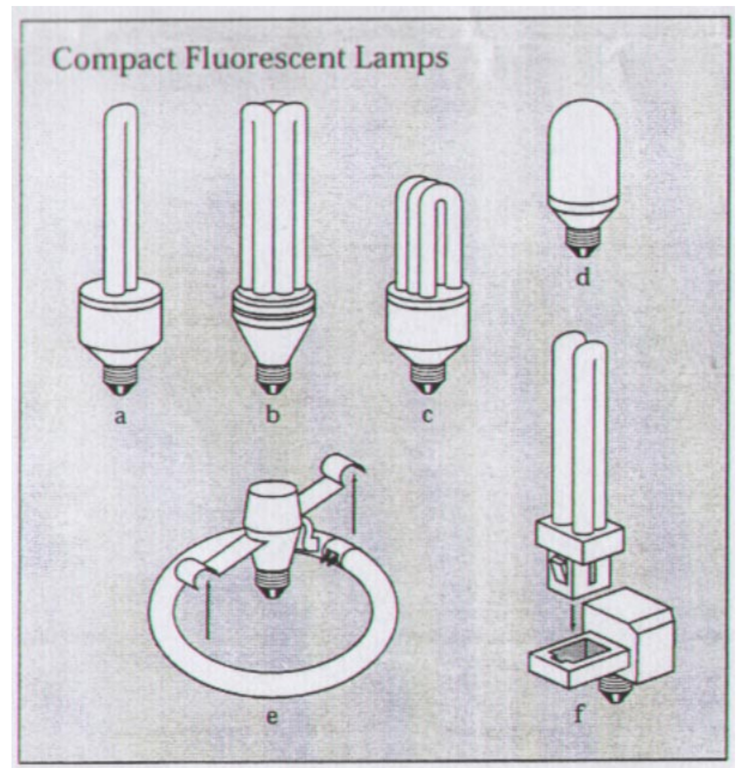
- Water source heat pump system (*COP* = 4.0 – 7.0)



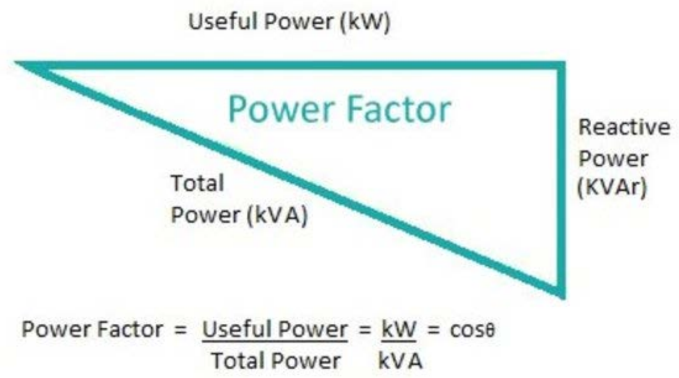
Lighting Systems



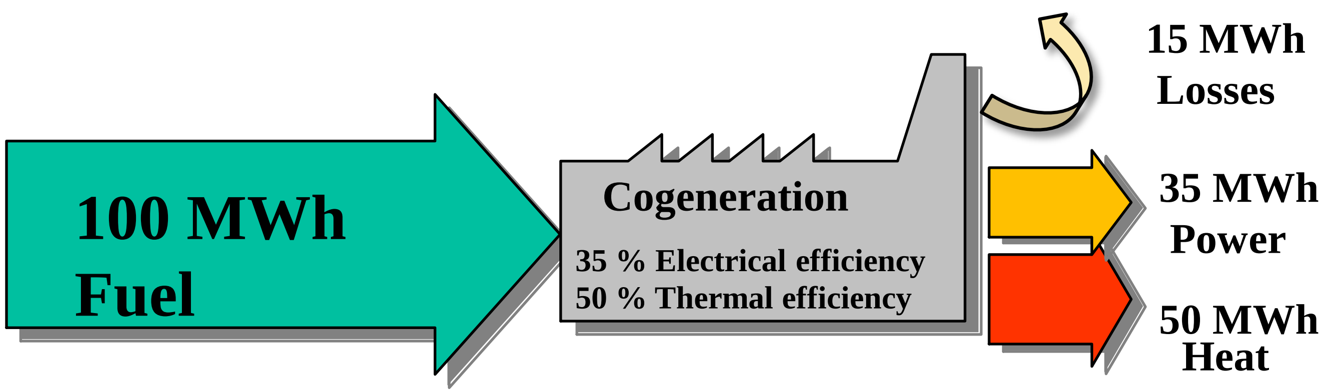
- Proper lighting levels
- Higher lamp efficiency
- Reduced operating hours
- Daylighting
- Lighting maintenance



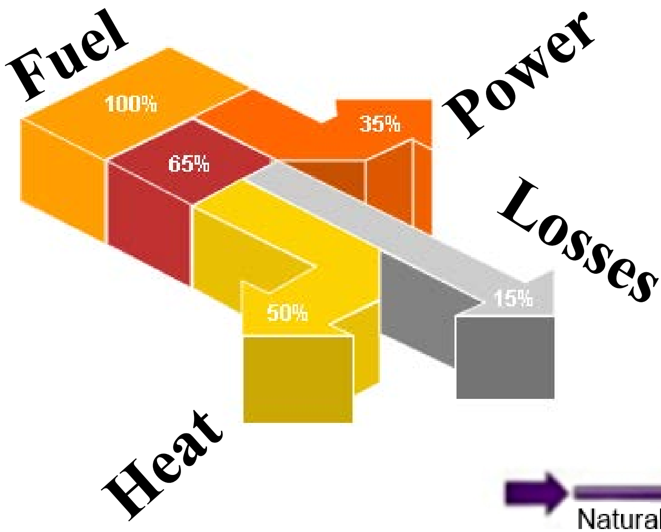
Power Systems

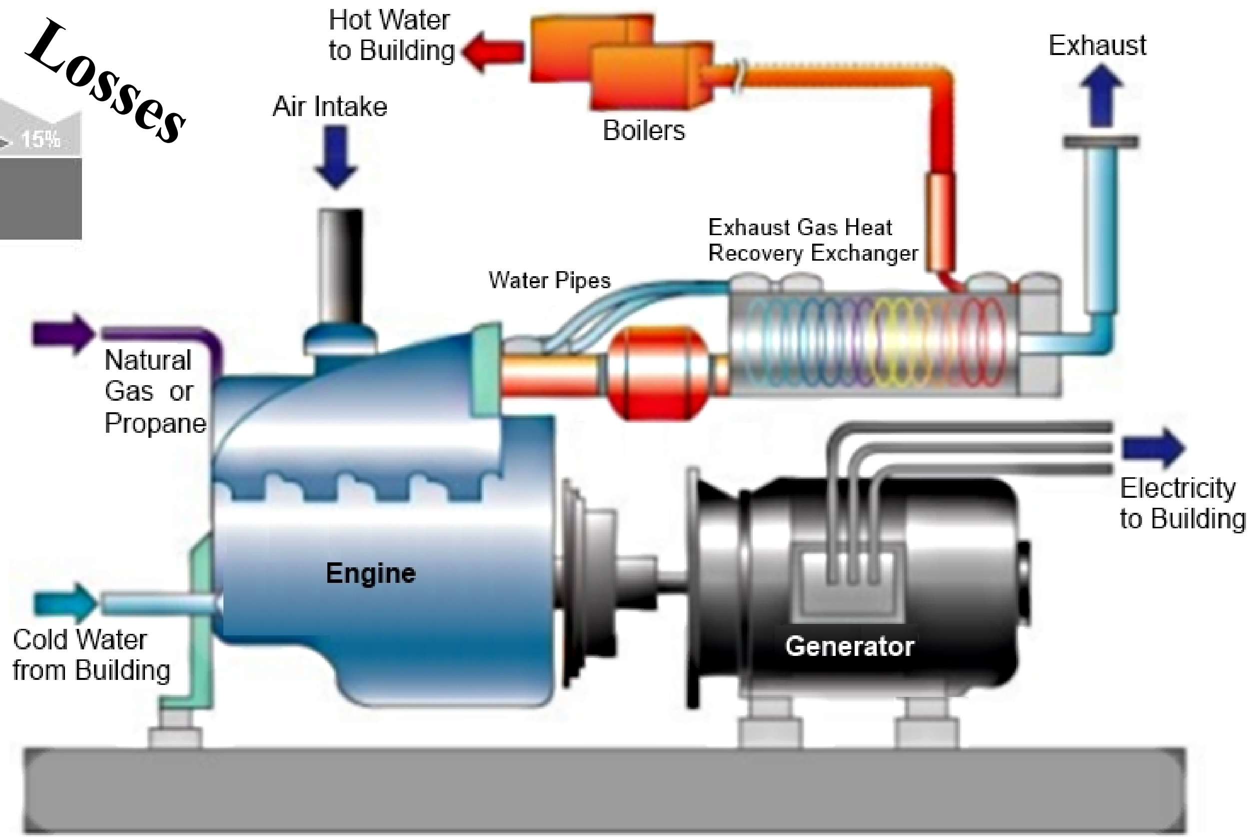


- Power Factor Correction
  (High efficiency motors, ballasts, correction devices)
- Improving Efficiency
  (Transformers, motor sizing, efficiency, and VSD)
- Demand Control
- Cogeneration



Efficiency with Cogeneration





Source: http://www.nscusa.com/chp/pmicogeneration.aspx

Heat Recovery Systems

Recuperator: A **recuperator** is a special purpose counter-flow heat exchanger used to recover waste heat from exhaust gases. In many types of processes, combustion is used to generate heat, and the recuperator serves to recuperate, or reclaim this heat, in order to reuse or recycle it.

Flue type recuperator

Radiation type recuperator

(Source: www.koreathermal.co.kr)

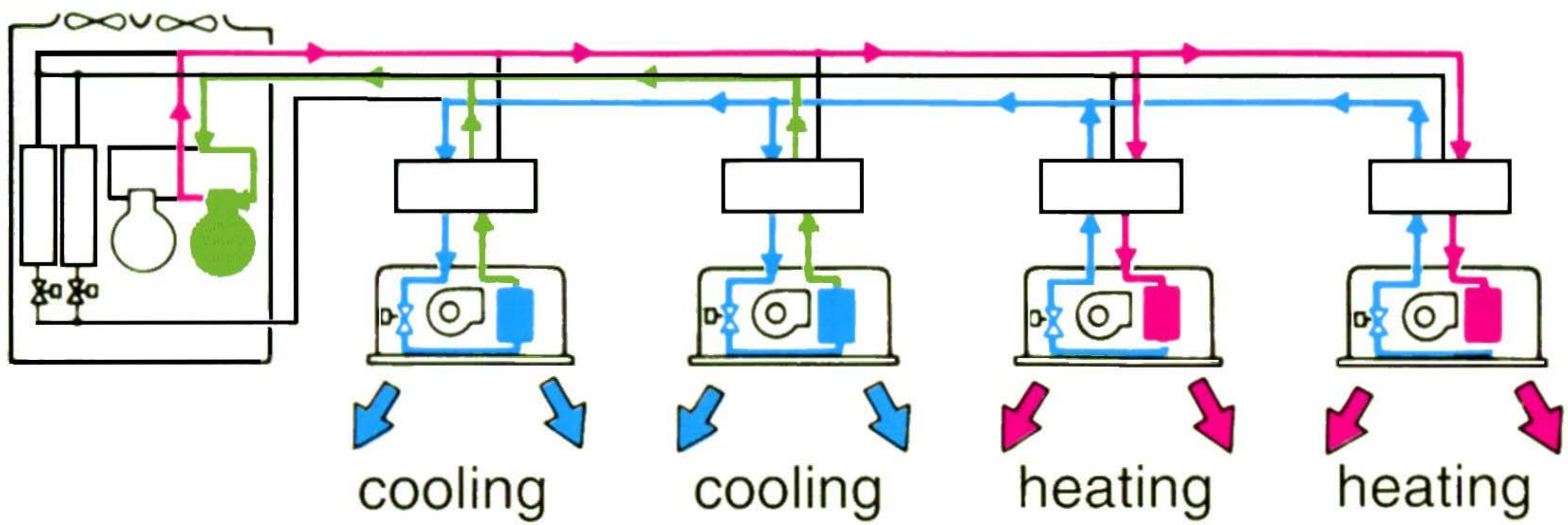
Heat Recovery Systems

- Heat recovery opportunities exist where there is a need to reject heat from a constant supply of high energy fluid such as air, water, or refrigerant.

- Possible opportunities are:
  - Hot drain water
  - Boiler stack or blow down
  - Exhaust air
  - Laundry air and water
  - Refrigeration and process load

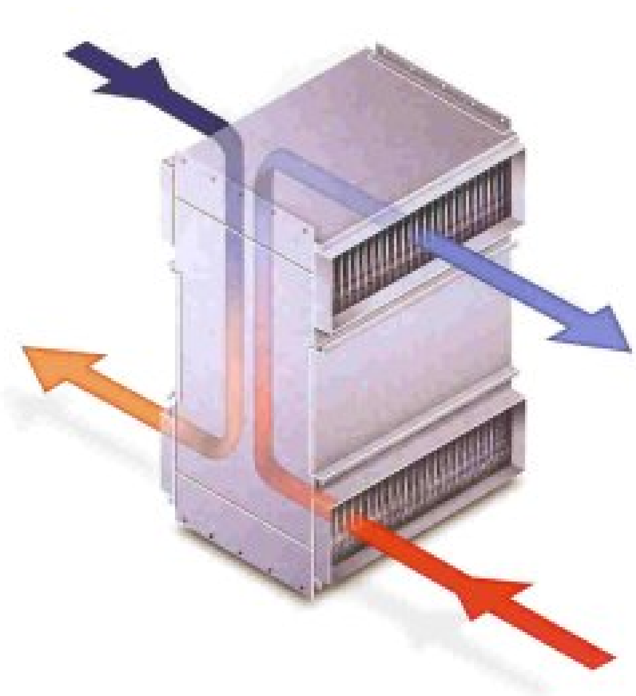
Heat Recovery heat pump or VRV System

- Cooling from evaporator and heating from condenser at the same time
- Sometimes the condenser is designed to heat water

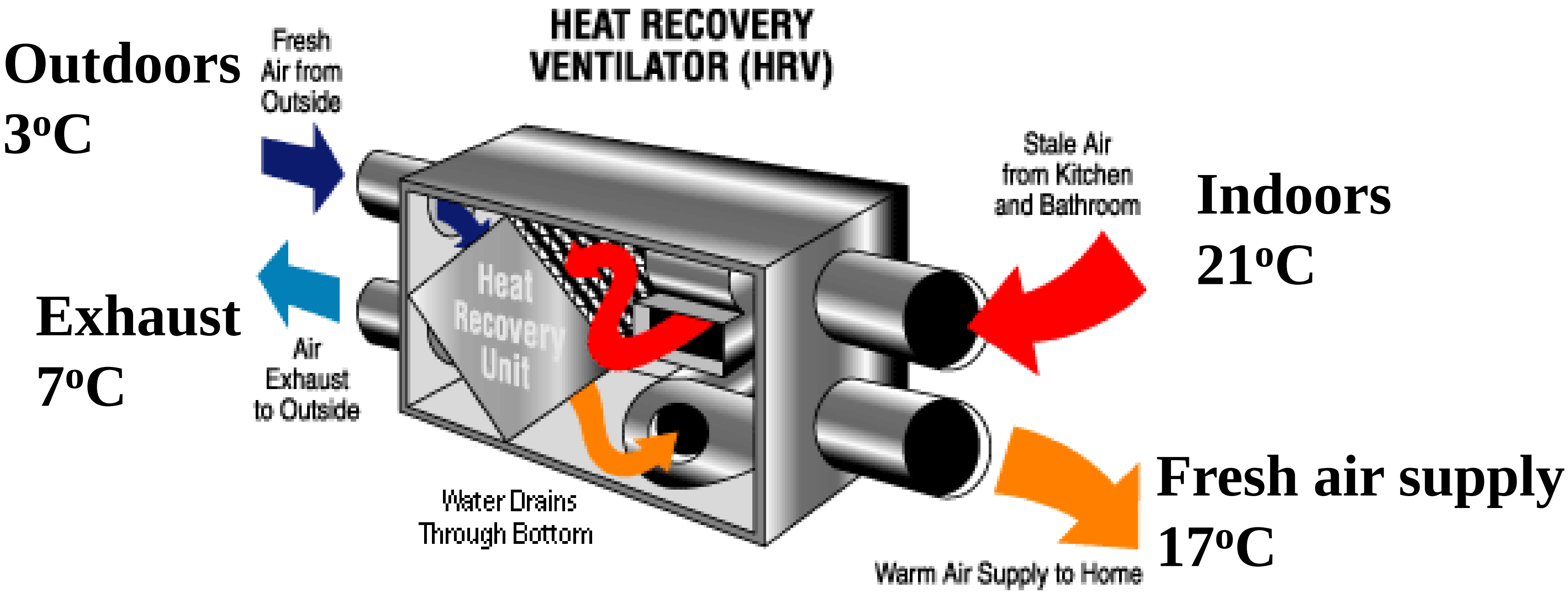


Heat Recovery Systems

Exhaust air heat recovery systems



Heat Recovery Ventillation System



Building Energy Management Systems

- Managing the **energy** and other needs in **buildings** efficiently and intelligently can have considerable benefits.
- A **building energy management system**(BEMS) is a sophisticated method to monitor and control the **building's energy** needs.

A computer based control system installed in buildings.

Energy Management Control Systems

- Minimize occupant control.
- Operate equipment only when needed.
- Eliminate or minimize simultaneous heating and cooling.
- Supply heating and cooling according to needs.
- Supply heating and cooling from most efficient source.

Communication

Automation